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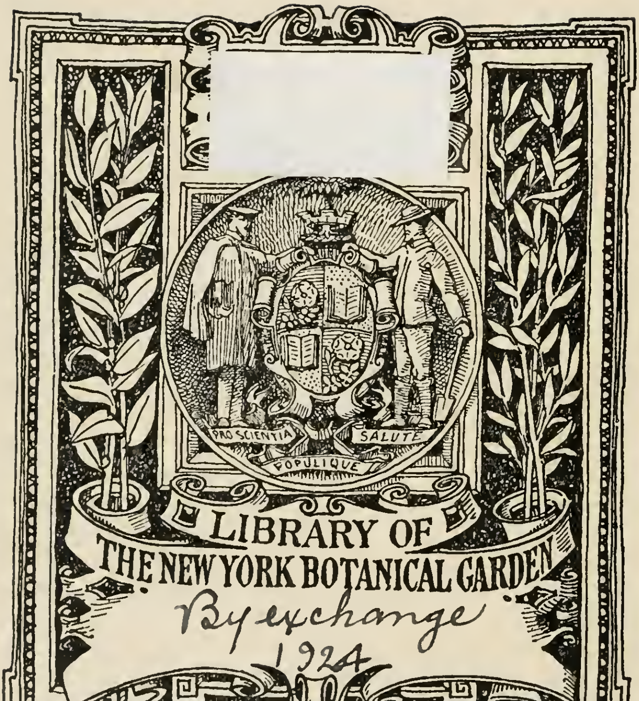
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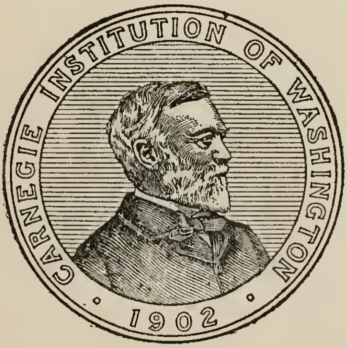
CARNEGIE INSTITUTION

OF

WASHINGTON

YEAR BOOK No. 22

NOVEMBER 1, 1922, TO OCTOBER 31, 1923



PUBLISHED BY THE CARNEGIE INSTITUTION OF WASHINGTON
WASHINGTON, FEBRUARY, 1924

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*Deceased.

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

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Laboratory for Plant Physiology:

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William A. Cannon.
J. M. McGee.
Forrest Shreve.
H. A. Spoehr.
Godfrey Sykes.

Department of Embryology:

George L. Streeter, Director.
Chester H. Heuser.
Margaret R. Lewis.
W. H. Lewis.
A. H. Schultz.

Department of Genetics:

Charles B. Davenport, Director.
A. F. Blakeslee, Assistant Director.
H. H. Laughlin, Assistant Director.
H. J. Banker.
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A. H. Estabrook.
M. Demerec.
J. A. Harris.
E. C. MacDowell.
C. W. Metz.
Oscar Riddle.

Geophysical Laboratory:

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L. H. Adams.
Eugene T. Allen.
N. L. Bowen.
C. N. Fenner.
J. W. Greig.
R. H. Lombard.
H. E. Merwin.
G. W. Morey.
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F. Hastings Smyth.
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Waldo G. Leland.
Charles O. Paullin.
Leo F. Stock.

Department of Marine Biology:

Paul Bartsch (U. S. National Museum).
Henry E. Crampton (Columbia University).
C. B. Lipman (University of California).
William H. Longley (Goucher College).
Asa A. Schaeffer (Clark University).
William A. Setchell (University of California).
D. H. Tennent (Bryn Mawr College).
T. Wayland Vaughan (U. S. Geological Survey).

Department of Meridian Astrometry:

Benjamin Boss, Director.
Sebastian Albrecht.
Sherwood B. Grant.
Heroy Jenkins.
Harry Raymond.
Arthur J. Roy.
W. B. Varnum.
Ralph E. Wilson.

Mount Wilson Observatory:

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Walter S. Adams, Director.
Alfred H. Joy, Secretary.
F. H. Seares, Supt. Computing Division.
A. S. King, Supt. Physical Laboratory.
J. A. Anderson.
Harold D. Babcock.
Ferdinand Ellerman.
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Milton Humason.
Paul W. Merrill.
Seth B. Nicholson.
Francis G. Pease.
Edison Pettit.
R. F. Sanford.
Gustaf Strömberg.
Charles E. St. John.
A. van Maanen.

* Deceased.

INVESTIGATORS FOR YEAR 1923—*continued.*

Nutrition Laboratory:

Francis G. Benedict, Director.
T. M. Carpenter.
E. L. Fox.
E. S. Mills.
P. P. Saponaro.

Department of Terrestrial Magnetism:

Louis A. Bauer, Director.
J. A. Fleming, Assistant Director.
J. P. Ault.
S. J. Barnett.
D. G. Coleman.
C. R. Duvall.
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John W. Green.
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H. F. Johnston.
W. A. Love.
S. J. Mauchly.
W. C. Parkinson.
W. J. Peters.
J. Shearer.
A. Thomson.
O. W. Torreson.
G. R. Wait.
W. F. Wallis.

Ecological Research:

Frederic E. Clements, Associate.
G. W. Goldsmith.
H. M. Hall.
Frances L. Long.
J. V. G. Loftfield.

Middle American Archæological Research:

Sylvanus G. Morley, Associate.

Physiological Chemistry:

T. B. Osborne, Research Associate (Connecticut Agric. Exper. Station).
L. B. Mendel, Research Associate (Yale University).
A. J. Wakeman.
C. S. Leavenworth.
Helen Cannon.
H. B. Vickery.

Biology:

T. H. Morgan, Research Associate (Columbia University).
C. B. Bridges.
A. H. Sturtevant.

Fellows of Institution:

Samuel F. Bemis (Whitman College), History.
A. P. Locke, Plant Physiology.
Franklin F. Snyder, Embryology.

Other Investigators:

Henry Bergen, Research Associate in Early English Literature.
Ralph W. Chaney, Research Associate in Palæobotany.
Oliver P. Hay, Associate in Palæontology.
Elias A. Lowe, Associate in Palæography.
Albert Mann, Research Associate in Biology.
George Sarton, Associate in the History of Science.
Esther B. Van Deman, Associate in Roman Archæology.
George R. Wieland, Associate in Palæontology.
Harry O. Wood, Research Associate in Seismology.

Additional Research Associates Connected with other Institutions:

Ernst Antevs, Geology.
Carl Barus (Brown University), Physics.
V. Bjerknes (University of Bergen, Norway), Meteorology.
E. C. Case (University of Michigan), Palæontology.

INVESTIGATORS FOR YEAR 1923—*continued.*

Additional Research Associates Connected with other Institutions—Continued.

W. E. Castle (Harvard University), Biology.
T. C. Chamberlin (University of Chicago), Geology.
A. L. du Toit (South Africa), Geology.
H. D. Fish (University of Pittsburgh), Zoology.
John F. Hayford (Northwestern University), Physics.
Ellsworth Huntington (Yale University), Geology.
Herman G. James (University of Texas), Political Science.
J. H. Jeans (Royal Society of London), Astronomy.
Waldemar Jochelson (Sweden), Archæology.
C. A. Kofoid (University of California), Zoology.
B. E. Livingston (Johns Hopkins University), Botany.
H. A. Lorentz (Netherlands), Physics.
Isabel McCracken (Stanford University), Biology.
A. A. Michelson (University of Chicago), Astronomy.
R. A. Millikan (California Institute of Technology), Physics.
Frank Morley (Johns Hopkins University), Mathematics.
F. R. Moulton (University of Chicago), Mathematical Physics.
E. L. Nichols (Cornell University), Physics.
A. A. Noyes (California Institute of Technology), Chemistry.
W. J. V. Osterhout (Harvard University), Botany.
T. W. Richards (Harvard University), Chemistry.
Robert W. Rogers (Drew Theological Seminary), History.
J. N. Rose (U. S. National Museum), Botany.
Henry N. Russell (Princeton University), Astronomy.
H. C. Sherman (Columbia University), Chemistry.
Edgar F. Smith (University of Pennsylvania), Chemistry.
John S. P. Tatlock (Stanford University), Literature.
Lewis H. Weed (Johns Hopkins University), Anatomy.
Bailey Willis (Stanford University), Seismology.

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ORGANIZATION, PLAN AND SCOPE.

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington.* (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the Trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and to printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

MAR 12 1924

ARTICLES OF INCORPORATION.

Public No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be in enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

Sec. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

Sec. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D.

Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

Sec. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

Sec. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

Sec. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

Sec. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

Sec. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

Sec. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

Article I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

Article II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

Article III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

Article IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

Article V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

Article VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

Article VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

OF THE

TWENTY-FOURTH MEETING OF THE BOARD OF TRUSTEES

ABSTRACT OF MINUTES OF THE TWENTY-FOURTH MEETING OF BOARD OF TRUSTEES.

The meeting was held in Washington in the Board Room of the Administration Building, on Friday, December 14, 1923, and was called to order at 10 a. m. by the Vice-Chairman, Mr. Walcott.

Upon roll-call the following Trustees responded: Robert S. Brookings, John J. Carty, W. Cameron Forbes, Herbert C. Hoover, Henry Cabot Lodge, Andrew J. Montague, William W. Morrow, James Parmelee, Wm. Barclay Parsons, Stewart Paton, Henry S. Pritchett, Charles D. Walcott, William H. Welch, Henry White, George W. Wickersham. The President of the Institution, John C. Merriam, was also present.

Upon motion it was voted to convey to the Chairman of the Board, Mr. Root, an expression of sympathy of the members of the Board on account of his illness, and of hope for his speedy recovery.

The minutes of the twenty-third meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Directors of Departments, Associates, and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1924 were authorized:

Insurance Fund	$8,000
Pension Fund	40,000
Administration	64,840
Publication (including Division of Publications)	95,000
Departments and Divisions of Research	940,444
Associates of Institution	20,600
Minor Grants	150,400
Index Medicus	10,000
General Contingent Fund	49,000
	$1,378,284

The resignation of Mr. Cleveland H. Dodge as a member of the Board was accepted with regret.

Mr. John J. Carty and Mr. Henry White were reelected as members of the Executive Committee to succeed themselves for a term of three years ending in 1926.

The meeting adjourned at 12^h30^m.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1923

REPORT OF THE PRESIDENT
OF THE
CARNEGIE INSTITUTION OF WASHINGTON.

In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, the President has the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1923, together with brief discussion of certain present problems and provisional recommendations of appropriations for the ensuing year.

Completed and Published Work.

A report covering the operations of the Institution for the past fiscal year must concern itself largely with the results of researches which have reached completion in the form of printed monographs and shorter papers. The most satisfactory form in which this statement can be made is that utilized in preparing the material in the Year Book for consideration at the time of the annual meeting of the Board of Trustees. By reason of the fact that only a few days elapse between the conclusion of our fiscal year and the time at which the report of the President is transmitted, it is necessary to submit the list of our publication activities included in this report in lieu of the full statement. The group of titles representing work actually completed and issued during the year is an impressive illustration of the activities of our Institution as a whole. Even a rapid review reveals both the quantity and the wide range of scientific problems to which the support of the Institution is given. It is particularly interesting to compare the list of publications of 1923 with the lists of other years and to realize that these contributions represent the continuing movement of the borders of knowledge into the field of the unknown.

Any attempt to review the scientific activities of the Institution in detail must be exceedingly superficial unless it is extended to limits which would approximate the extent of condensed reports constituting the bulk of our Year Book for 1923. It is, however, proper to call attention to special movements or changes in the activities of the past year which may be recognized as typical of our progress.

The work of the three great departments of the Institution concerned with the investigation of fundamental physical phenomena, namely, Mount Wilson Observatory, Geophysical Laboratory, and Department of Terrestrial Magnetism, has continued its course of uninterrupted progress through the past year. Many investigations of importance have been completed and are reported in the lists of publications.

Progress at Mount Wilson Observatory.

The program of cooperation of Mount Wilson Observatory with California Institute of Technology in an investigation of the structure of matter, as discussed in previous reports, has justified itself abundantly by the continuing success of these studies, both in observational and laboratory work at Mount Wilson and in the laboratories of California Institute. The skillfully designed and brilliantly executed plan of Mount Wilson Observatory for investigation of the eclipse of the sun in September failed to secure the tangible results which average conditions would lead one to expect, but the construction of the new 50-foot interferometer, which will extend considerably the possibility for study of fixed stars, was advanced greatly by the need for use of a portion of this mechanism in connection with observation of the eclipse. There is no doubt that great discoveries made possible by the interferometer will be much advanced by this circumstance. Moreover, the splendid spirit with which the staff of the Observatory carried out the plans for observation on this occasion can not help but bring its return in very many ways through the routine of the coming year's work.

As is indicated in the special report of Mount Wilson Observatory, this year has seen the bringing to fruition of the effort initiated by Dr. Hale some years ago, to construct a ruling machine for the purpose of preparing diffraction gratings to be used in connection with special studies for which the major instruments of Mount Wilson Observatory are particularly adapted. After a long period of construction, in which many peculiar obstacles have been overcome, the ruling machine has finally reached a stage of full success and produces gratings of unusually fine quality. The completion of this and other important mechanical aids, together with additional significant progress in the development of the instruments of Mount Wilson, makes certain a continuing and rapid advance in many of the most fundamental investigations of the immediate future.

The report of scientific studies completed and of discoveries recorded at Mount Wilson during the present year would include in one direction the rapid development of the study of wire explosions at very high temperatures for comparison with the phenomena studied on the sun; in another direction the recent discovery that the magnetic polarity of sun-spots in both northern and southern hemispheres of the sun is reversed in the spots of the new cycle coming in; and in still another field includes the securing of definite evidence regarding the internal motions of the great spiral nebulæ which are among the most interesting objects in the heavens.

Problems of Geophysical Laboratory.

Turning from the work of Mount Wilson Observatory, which looks out over the surrounding universe, we find the Geophysical Laboratory attaining comparable success in its attack upon the difficult problems concerning that little-known realm represented by the interior of the earth. Here the most fundamental researches in physics and chemistry are brought to bear in an effort to secure evidence regarding conditions prevailing in a region for which immediate visual exploration is impossible. As in the study of the sun at Mount Wilson, we have in this Laboratory a series of experiments under way for the purpose of developing for immediate research purposes a group of conditions similar to those existing in the special region being examined, which in this case is the interior of the earth. The results of this work in the past year are embraced in many publications touching, on the one hand, the most intimate problems of atomic structure of minerals or elements concerned in the physical or chemical processes investigated; they extend, on the other hand, to a study of materials emanating from the interior of the earth, as in examination of the lavas of the Hawaiian Islands, and the chemical investigation of fumaroles of the Katmai region of Alaska.

The student of the interior of the earth does not have advantage of the phenomena based on light transmission, such as enable the astronomer to view changes in progress on the sun and stars; but, not to be denied an immediate living touch with the field of his investigations, the geophysicist avails himself of other types of vibration, and through the study of earthquake waves and by other means becomes in some measure aware of present conditions in the earth's interior.

Earthquake Investigation.

Inasmuch as earlier reports have directed attention to a cooperative research of unusual character aimed toward solution of certain critical problems in earthquake study, it is appropriate at this time to note that a very large measure of progress has been realized in these investigations within the last year. The report of activities presented in the Year Book by Dr. Arthur L. Day, chairman of the committee, is an extremely interesting story.

Among other significant contributions recorded, it should be noted that in three of the subjects in which cooperative work was undertaken additions to knowledge have been made which rank as epoch-making in these fields. The work of the Coast and Geodetic Survey in demonstrating horizontal movements of the earth's crust, amounting to many feet over a considerable part of California, opens a new field not only for seismology and geology but also for geography. In mapping the floor of the Pacific Ocean off the southern coast of California out to the 2,000-fathom line, by use of the sonic depth-finder or the "echo" method, the Hydrographic Office of the United States Navy opened a new chapter in study of the sea. The construction of a new but extremely simple and effective seismograph by Dr. Anderson, of Mount Wilson Observatory, clears the way for new researches in the history of earthquake phenomena having special reference to definite lines of fracture in the earth's crust.

In addition to the previously planned investigations into the nature and effect of earthquakes the generosity of the Carnegie Corporation of New York at a critical moment made it possible to send a representative of the Institution to Chile for the purpose of studying problems arising out of the earthquake of November 1922. Dr. Bailey Willis, who undertook this work, received most cordial support and every possible assistance from the Government of Chile and from its representatives in all departments. The results of this study have given us a valuable interpretation of movements of the crust of the earth in Chile involving origin and growth of the Andes Mountains. In addition to the fundamental researches in seismology, Dr. Willis gave special attention to interpretation of earthquake phenomena in terms of the engineering phase of building construction considered with special reference to immediate needs of the people of Chile.

Terrestrial Magnetism.

In the Department of Terrestrial Magnetism another kind of investigation involves the phenomena of magnetism, electricity, and gravity as expressed in our earth as a unit. Consideration of these aspects of the earth relates itself on the one hand to problems of astronomy and on the other side to questions arising in the Geophysical Laboratory. Although the method of approach in this study of the physics of the earth is widely different from that in the special fields of our other great laboratories, it is inevitable that in final consideration of the data secured the results will in considerable measure assist in explanation of phenomena examined by other investigators.

Following recent completion of an extended survey of the sea made possible by the non-magnetic ship *Carnegie*, the Department of Terrestrial Magnetism has placed special emphasis during the past year on the extension of its land observations, with a view to securing adequate data for generalizations on problems concerning the earth's magnetism. On occasion of the eclipse of the sun in September, the Department made a group of important observations at Point Loma and at other stations.

The work of the Department in bringing together all available knowledge on magnetic variation and in adding enormously to the world's stock of observational data through its own expeditions is a contribution of exceptional significance. Not only will it furnish much of the information needed for local and special studies, but it gives as well a large part of the basic material required for those fundamental researches on the earth's physical phenomena which will unquestionably characterize the next stage in study of the earth as a physical unit.

In development of the researches of this Department during the next cycle of its growth, the combined burden of observation and interpretation may be so adjusted as to permit us to carry the relatively large share of observational work borne up to this time. On the other hand, it may prove desirable to enter into such cooperative relations with other active agencies in various parts of the world as will facilitate the distribution of this work, thus affording the largest opportunity for accumulation of data and for translation of these materials into interpretations of the laws or modes of action of the forces represented.

Embryology.

In the departments of the Institution concerned with biological studies, effort has been made in the past year to bring about such an interrelation of the various activities as would make possible a more effective attack through mutual support in related activities and a more rapid advance. The endeavor has also been made to relate the work of the departments to that of other research agencies in such a manner as to permit fullest cooperation.

An interesting development in the work of the Institution relating to study of human behavior appears in a cooperative arrangement between our Department of Embryology and Dr. Lewis H. Weed, Professor of Anatomy and Dean of the Medical School of the Johns Hopkins University. In the program for human-behavior studies outlined by the special committee cooperating with the Institution, emphasis has been placed on the necessity for investigation of fundamental physiological reactions of the individual in its earliest stages. There has been increasing evidence of need for study of the physiological reactions in all embryonic material available for investigation coupled with adequate morphological control. A program of research has now been outlined which will make it possible to take immediate advantage of every opportunity for these exceedingly important and critical studies.

In the special researches conducted independently by the Department of Embryology, significant advances have been made in many directions, ranging from a study of fundamental problems concerning growth of tissues in the body to the value of racial characteristics in early embryonic stages. The work of W. H. Lewis in this Department gives us this year for the first time a demonstration of the manner in which one of the primitive embryonic tissues in the body known as "indifferent mesenchyme" becomes converted into such highly specialized membranes as those lining the thoracic and abdominal cavities.

Genetics and Ecology.

Through studies carried on in many laboratories in recent years, a great body of knowledge has been accumulated which bears upon the mechanism of heredity. While very much remains to be known in this field, classic researches like those of T. H. Morgan, a distinguished associate of the Institution, have gone far to give us an understanding of the process by which the characteristics of individuals are carried over or combined in succeeding generations.

In our Department of Genetics significant advances have been made in studies conducted by A. F. Blakeslee and John Belling on variation in the elements of the cell recognized as bearers of characters transmitted to descendants. In addition to investigation of the mechanism of the cell in its relation to heredity, progress has been made on the experimental side in the induction of mutations or variations in certain plants and in the interpretation of factors which seem to have produced such variation of the cell structure.

One of the great opportunities for future research in biology seems to lie in the consideration of influences which alter the course of life succession. There is strong suggestion that determination of the characteristics of a given generation may not depend solely upon elements contributed directly by the ancestor or ancestors. Influences external to the original elements of the cell, exerted perhaps by purely physical or chemical processes, may be responsible for some of the deviations from original type.

The difference between a situation in which the qualities of a new individual depend entirely upon original characteristics of the ancestors, and one in which the individual peculiarities are even in small part due to new conditions or influences, corresponds to the distinction between a process in which the nature of each series of individuals is predetermined and one in which the direction of modification may be turned away slightly from the path marked out by heredity. According to the first process, growth or evolution in the life world may work out its own course. Under the second possibility the characteristics of an individual are determined in the main by its ancestry with the added chance of modification, depending upon special influences, internal or external, affecting the cells from which the individual originates. One condition gives a life world with relatively narrow limits for advance; the other makes life more clearly plastic and opens a wider range of opportunity for directed growth or evolution.

The researches of the Division of Ecology, devoted to consideration of relation of the life process to the biological and physical environment, involve the problem of life succession or growth or evolution seen from a point of view rather different from that of the geneticist. The results of the ecologist's investigations contribute toward the solution of our growth problem certain elements which are of great importance in any attempt to estimate the nature of biological succession. The mutual support of the geneticists and ecologists through the machinery offered by the Institution is certain to give us an understanding of some of the critical phenomena bearing upon evolution, such as will be needed in the next stage of advance in biology. In this division several significant contributions have been made this year, among which is the important publication by Hall and Clements on "The phylogenetic method in taxonomy."

Marine Biology.

Since the death in 1922 of Alfred G. Mayor, head of our Department of Marine Biology, we have attempted to advance to their natural culmination the studies initiated under Dr. Mayor's guidance. We have also made the Marine Biological Laboratory at the Dry Tortugas available to those of Dr. Mayor's associates desiring the advantages of this favorable collecting-ground, together with equipment and field assistance for biological research. In the course of the past year the President visited the Tortugas Laboratory, as also a number of the sites for biological stations in the Gulf region and on the east coast of Florida. A careful study of the possible needs for continuation of the work in marine biology has been carried out through conferences with many of the leading biologists in this country.

The immediate future of our work in marine biology depends on the urgency of need for well-organized investigations in fundamental questions requiring an equipment such as is available at our Laboratory.

It must depend also upon the significance of such needs in contrast to the requirements of other researches conducted by the Institution, which already indicate quite definitely that they are giving returns of large value to science.

During the season of 1924 the Tortugas Laboratory should be open with provision for a number of interesting studies already proposed. The remoteness of the station from centers of active research and the difficulty of holding the quarters available through the entire year have constituted a considerable handicap in planning wider use of the Laboratory. So far as it is possible, the facilities at our command are being made fully available.

Early American History.

In the course of the past ten years numerous exploration parties sent out by the Institution have made studies of remains representing the ancient Maya civilization which extended from southern Mexico through Guatemala. As this work advanced it became clear that the initial reconnaissance should be followed by intensive research on important sites or cities in which the principal phases of Maya culture could be investigated to best advantage.

In order to secure an understanding of the conditions under which such work might be conducted, the President of the Institution visited Yucatan early in the past year in company with General Wm. Barclay Parsons, of the Board of Trustees, and S. G. Morley, Associate in Middle American Archæology in the Institution. Subsequently the President and Dr. Morley visited the City of Mexico in order to confer with officials of the Federal Government relative to these investigations. As a result of these visits and conferences the Mexican Government has courteously extended to the Institution the privilege of entering upon a ten-year program of investigation in Yucatan, at Chichen Itzá, a large and important Maya city with a history extending over at least a thousand years. The initial steps for carrying out this study have already been taken by the Institution and active work on the site is planned for January 1924.

The plan of study of Chichen Itzá concerns the broader problem of early American history as it can be interpreted through the Maya civilization. Along with specifically archæological investigations touching the history of engineering, architecture, art, and the stratigraphic sequence of cultures, the researches will include a study of the physical characters of the race and of the environment in which it developed. In order to understand these people as they lived and to secure information concerning their industries and their agriculture, it is necessary to know the limitations imposed by geological, climatological, and other physical conditions determining the development of the plants and animals upon which the inhabitants were dependent. The studies proposed will naturally require the assistance of a considerable group of specialists and it is hoped that through cooperation of other agencies and institutions interested in this work a thoroughly fundamental investigation may be carried out.

In planning the proposed researches on early American civilizations the effort has been made so to organize our studies that the information obtained may have the maximum value for interpretation of present and future problems concerning the people of Middle America. Through all of the stages of preparation for this work it has been most gratifying to have the hearty cooperation and support of the governments of the Middle America region and also of all institutions and individuals of these countries in any way concerned with this research.

Lectures.

The series of lectures on results of recent researches, which was initiated in 1921, was continued in the winter and spring of 1922–23. It is considered an important personal means of interpreting to the scientific public some of the results of current investigations. The following titles represent the lectures given during the past year:

November 7, 1922. The heat of the sun and other stars. C. G. Abbot.
November 21, 1922. The greater problems of the earth's magnetism and their bearing on astronomy, geology, and physics. L. A. Bauer.
November 28, 1922. The constitution of the hereditary material and its relation to development. T. H. Morgan.
December 5, 1922. The properties of matter as illustrated in the stars. H. N. Russell.
December 12, 1922. The motions of the stars. W. S. Adams.
April 19, 1923. Present problems in the field of atomic structure and their bearing upon the nature of ethereal radiations. R. A. Millikan.
April 25, 1923. Application of interference methods to astronomical problems. A. A. Michelson.

It is interesting to note that the lectures by Dr. Abbot on the heat of the sun and other stars, by Dr. Russell on the properties of matter as illustrated in the stars, by Dr. Adams on the motions of the stars, by Dr. Millikan on atomic structure, and by Dr. Michelson on the application of interference methods, all relate to the extraordinarily interesting program of cooperative research involving the staff of Mount Wilson Observatory and a considerable group of associate investigators closely related to and cooperating with the Institution in its studies in the field of astrophysics.

In the same way the lecture on the greater problems of the earth's magnetism has brought out the intimate relation between problems of the physics of the earth and many of the fundamental questions of astronomy and geology. The lecture by Dr. Morgan, on the hereditary material and its relation to development, set forth in an extraordinarily interesting manner the results of Dr. Morgan's epoch-making studies in these problems.

In the first half of the coming year the lecture series is continued through presentation by Dr. Arthur L. Day, chairman of our committee on earthquake investigations, of results coming from the recent cooperative attack on the problem of seismology. In the field of research in history Dr. Jameson will discuss a problem in diplomatic history in a lecture entitled "The approach to diplomatic history illustrated by the correspondence of the early British ministers to the United States."

Fellowships.

In 1921 a plan was approved for establishment of a small group of fellows in the Institution for the purpose of offering opportunity for association with our staff to a limited number of persons desiring to take up work in the Institution on a temporary basis. This plan was initiated with the understanding that the fellows of the Institution would be persons having exceptional interest in research and adequate preparation for undertaking work on problems relating to our general program. Appointments of fellows have been made in the Departments of Embryology, History, Plant Physiology, and Geophysical Laboratory.

Salary Scale.

In the preparation of recommendations for the budget of the coming year the problem of salary scale or financial compensation for the staff of the Institution has been the subject of careful investigation. Although the Institution has made large additions to the salary budget in the course of the past decade and has also increased the rate of compensation as compared with the level of pre-war time, our standard of compensation for a considerable group of our leading investigators is below that of the principal universities and much below the compensation for constructive work or research in commercial life. Readjustments have been made in various directions in a number of departments in order to better the salaries without diminishing effectiveness in operation of the plant, but we are still left in a situation in which the continuing loyal support of the Institution's work by the members of the staff is in many cases possible only through considerable financial sacrifice.

Financial Statement for Fiscal Year 1922-1923.

The sources of funds available for expenditure during the fiscal year (including appropriations made by the Trustees December 15, 1922, and revertments and transfers made during the year), the amounts allotted by the Executive Committee during the year, and the balances unallotted at the end of the year are shown in detail in table A:

A.—Financial statement for fiscal year ending October 31, 1923.

	Balances unallotted Oct. 31, 1922.	Trustees' appropriation Dec. 15, 1922.	Revertments and transfers Nov. 1, 1922, to Oct. 31, 1923.	Total available 1923.	Executive Committee allotments 1923.	Transfers by Executive Committee.	Unallotted balances Oct. 31, 1923.
Large Grants:							
Laboratory for Plant Physiology	...	$55,500	$500.00	$56,000.00	$56,000.00	...	...
Embryology	...	43,940	...	43,940.00	43,940.00	...	...
Ecological Research	...	32,500	500.00	33,000.00	33,000.00	...	...
Genetics	...	119,000	2,290.00	121,290.00	121,290.00	...	...
Geophysical Laboratory	...	140,772	6,350.00	147,122.00	147,122.00	...	...
Historical Research	...	40,980	...	40,980.00	40,980.00	...	...
Marine Biology	...	9,320	...	9,320.00	9,320.00	...	...
Meridian Astrometry	...	38,012	...	38,012.00	38,012.00	...	...
Middle Amer. Archæology	...	17,425	4,000.00	21,425.00	21,425.00	...	...
Nutrition Laboratory	...	43,730	400.00	44,130.00	44,130.00	...	...
Mt. Wilson Observatory	...	221,804	2,000.00	223,804.00	223,804.00	...	...
Terrestrial Magnetism	...	164,679	1,200.00	165,879.00	165,879.00	...	...
Minor Grants	$2,100.00	186,485	7,393.37	195,978.37	187,139.00	$7,839.37	$1,000.00
Publications	4,879.73	92,500	9,998.94	107,378.67	103,041.60	...	4,337.07
Administration	...	63,500	...	63,500.00	63,500.00	...	...
Insurance Fund	...	9,500	...	9,500.00	9,500.00	...	...
Pension Fund	...	40,000	...	40,000.00	40,000.00	...	...
General Contingent Fund	2,250.00	45,000	37,249.81	84,499.81	2,339.87	74,049.94	8,110.00
	9,229.73	1,364,647	71,882.12	1,445,758.85	1,350,422.47	81,889.31	13,447.07

B.—*Aggregates of financial receipts.*

Year ending Oct. 31.	Interest on endowment.	Interest on bonds and bank deposits.	Sales of publications.	Refunds on grants.	Miscellaneous items.	Total.
1902	$250,000.00	$9.70	...	...	$1,825.52	$251,835.22
1903	500,000.00	5,867.10	$2,286.16	...	101.57	508,254.83
1904	500,000.00	33,004.26	2,436.07	$999.03	...	536,439.36
1905	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944.73
1911	975,000.00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.97
1912	1,100,000.00	31,118.41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913	1,103,355.00	46,315.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914	1,105,084.17	59,298.63	11,402.40	7,819.70	577,305.77	1,760,910.67
1915	1,100,375.00	67,888.31	10,297.79	8,322.87	28,162.79	1,215,046.76
1916	1,100,375.00	83,626.38	12,544.16	1,450.12	153,204.40	1,351,200.06
1917	1,100,408.75	100,702.60	11,921.35	32,950.22	179,611.97	1,425,594.89
1918	1,110,427.45	120,464.02	9,921.00	39,833.23	255,354.60	1,536,000.30
1919	1,112,441.25	138,700.73	12,837.58	53,549.98	214,498.99	1,532,028.53
1920	1,112,441.25	159,559.03	18,393.79	4,088.63	176,249.81	1,470,732.51
1921	1,112,441.25	170,211.22	16,684.51	4,068.69	210,518.96	1,513,924.63
1922	1,112,504.52	175,021.09	14,081.84	9,395.66	34.527.38	1,345,530.49
1923	1,114,633.56	192,195.29	13,841.76	9,739.17	1,720,808.90	3,051,218.68
Total	18,759,487.20	1,517,329.11	214,190.02	190,341.78	*4,201,414.95	24,882,763.06

*Of this amount, $3,131,642.22 came from the sale of bonds in 1908, 1909, 1910, 1912, 1913, 1914, 1915, 1916, 1917, 1918, 1921, 1922, and 1923; $51,265.74 from the Colburn Estate in 1916; and $960,000 from the Carnegie Corporation of New York in 1917, 1918, 1919, 1920, 1921, 1922, and 1923.

Receipts and Expenditures of the Institution to Date.

The aggregates of receipts from interest on endowment, from interest on bond investments and bank deposits, from sales of publications, from refunds on grants, and from miscellaneous sources, for each year since the foundation of the Institution, are shown by table B (page 13); the grand total of these to date is $24,882,763.06.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be classified under five heads: (1) Investments in bonds; (2) large projects; (3) minor grants and payments from Pension and Insurance Funds; (4) publications; (5) administration. Table C shows the actual expenditures under these heads for each year since the foundation of the Institution.

C.—*Aggregate of expenditures.*

Year ending Oct. 31.	Purchase of bonds.	Large projects.	Minor grants and payments from Pension and Insurance Funds.	Publications.	Administration.	Total
1902	....	....	$4,500.00	....	$27,513.00	$32,013.00
1903	$100,475.00	....	137,564.17	$938.53	43,627.66	282,605.36
1904	196,159.72	$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910	57,889.15	427,941.40	83,464.63	49,067.00	44,011.61	662,373.79
1911	51,921.79	454,609.75	72,048.80	37,580.17	45,455.80	661,616.31
1912	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913	666,428.03	698,337.03	110,083.06	53,171.59	43,552.89	1,571,572.60
1914	861,864.23	817,894.52	107,507.55	44,670.55	44,159.54	1,876,096.39
1915	206,203.21	770,488.58	109,569.37	46,698.56	48,224.04	1,181,183.76
1916	473,702.70	638,281.41	99,401.26	73,733.38	49,454.08	1,334,572.83
1917	502,254.05	695,813.07	100,746.13	62,884.61	48,766.29	1,410,464.15
1918	528,565.55	693,780.00	170,470.74	44,394.83	49,118.76	1,486,329.88
1919	438,960.29	845,123.82	203,810.84	68,964.23	55,742.83	1,612,602.01
1920	464,279.57	876,437.28	159,633.49	95,933.10	68,739.90	1,665,023.34
1921	109,390.25	981,186.46	171,895.22	81,388.33	58,730.11	1,402,590.37
1922	50,431.05	975,149.20	192,325.46	96,227.01	56,405.15	1,370,537.87
1923	1,715,537.72	930,395.95	232,344.69	89,402.06	63,493.46	3,031,173.88
Total	7,162,256.99	12,470,848.56	2,741,282.62	1,120,327.18	1,047,156.57	24,541,871.92

Investments in Property.

On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments, the following sums have been expended since the foundation of the Institution:

D.—*Real estate and equipment, original cost.*

Administration:		
Building, site, and equipment		$340,315.69
Laboratory for Plant Physiology (Sept. 30, 1923):		
Buildings and grounds	$54,705.41	
Laboratory and library	28,362.65	
Operating appliances	11,863.28	
		94,931.34
Ecological Research (Dec. 31, 1921):		
Building, Laboratory	4,547.00	
Library, operating	2,069.88	
		6,616.88
Department of Embryology (Sept. 30, 1923):		
Library	1,203.15	
Laboratory	7,351.13	
Administration	3,846.93	
		12,401.21
Department of Genetics (Sept. 30, 1923):		
Buildings, grounds, field	265,153.15	
Operating	19,629.13	
Laboratory apparatus	11,950.12	
Library	22,290.71	
Archives	45,488.90	
		364,512.01
Geophysical Laboratory (Sept. 30, 1923):		
Building, library, operating appliances	189,782.61	
Laboratory apparatus	92,446.29	
Shop equipment	11,197.73	
		293,426.63
Department of Historical Research (Sept. 30, 1923):		
Office	3,138.92	
Library	4,537.13	
		7,676.05
Department of Marine Biology (Sept. 30, 1922):		
Vessels	30,930.43	
Buildings, docks, furniture, and library	12,130.86	
Apparatus and instruments	9,322.55	
		52,383.84
Department of Meridian Astrometry (Sept. 30, 1923):		
Apparatus and instruments	3,257.34	
Operating	3,560.60	
		6,817.94
Nutrition Laboratory (Sept. 30, 1923):		
Building, office, and shop	124,083.83	
Laboratory apparatus	26,972.28	
		151,056.11
Mount Wilson Observatory (Aug. 31, 1923):		
Buildings, grounds, road, and telephone line	197,207.27	
Shop equipment	39,354.53	
Instruments	497,870.66	
Furniture and operating appliances	162,432.71	
Hooker 100-inch reflector	597,448.87	
		1,494,314.04
Department of Terrestrial Magnetism (Sept. 30, 1923):		
Building, site, and office	205,643.66	
Vessel and survey equipment	173,248.26	
Instruments, laboratory, and shop equipment	109,247.30	
		488,139.22
		3,312,590.96

Sales of Publications and Value of those on Hand.

Table E shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution.

E—*Table showing sales of publications.*

Year.	Index Medicus.	Year Book.	Miscellaneous books.
1903.....	$2,256.91	$29.25	....
1904.....	2,370.47	52.85	$12.75
1905.....	2,562.76	44.75	431.44
1906.....	2,970.56	37.60	1,341.52
1907.....	3,676.71	56.50	2,292.89
1908.....	3,406.19	99.65	4,371.67
1909.....	4,821.85	73.01	6,287.21
1910.....	4,470.50	100.70	5,899.05
1911.....	4,440.21	85.50	6,366.55
1912.....	4,652.14	61.65	6,782.34
1913.....	4,992.02	75.95	7,140.69
1914.....	5,079.16	49.65	6,273.59
1915.....	5,010.21	47.60	5,239.98
1916.....	4,382.19	46.60	8,115.37
1917.....	4,616.21	51.55	7,253.59
1918.....	4,324.29	21.10	5,575.61
1919.....	4,267.95	93.30	8,476.33
1920.....	5,451.86	40.50	12,901.43
1921.....	6,277.32	50.55	10,356.64
1922.....	5,774.59	59.25	8,248.00
1923.....	5,777.46	70.10	7,994.20
Total...	91,581.56	1,247.61	121,360.85

At the end of the fiscal year there are on hand 91,666 volumes of miscellaneous publications and Year Books, having a sale value of $274,847.28; also 31,702 numbers of the Index Medicus, having a value of $19,403.75. The total value of publications on hand is therefore $294,251.03.

Growth and Extent of Institution's Publications.

The data furnished in table F are of statistical interest in respect to the work of publication of the Institution. 486 volumes, which embrace a total of 137,829 pages of printed matter, have thus far been issued.

F.—*Table showing number of volumes, number of pages (octavo and quarto), and totals of pages of publications issued by the Institution for each year and for the twenty-one years from 1902 to 1923.*

Year.	Number of volumes issued.	Number of octavo pages.	Number of quarto pages.	Total number of pages.
1902......	3	46	....	46
1903......	3	1,667	....	1,667
1904......	11	2,843	34	2,877
1905......	21	3,783	1,445	5,228
1906......	19	3,166	1,288	4,454
1907......	38	6,284	3,428	9,712
1908......	28	4,843	2,485	7,328
1909......	19	3,695	1,212	4,907
1910......	29	3,274	4,831	8,105
1911......	30	5,062	1,670	6,732
1912......	23	3,981	2,044	6,025
1913......	29	6,605	2,752	9,357
1914......	23	4,978	1,934	6,912
1915......	23	4,686	1,466	6,152
1916......	35	9,478	2,430	11,908
1917......	21	4,464	2,691	7,155
1918......	17	3,073	1,120	4,193
1919......	29	5,834	2,431	8,265
1920......	23	3,962	3,710	7,672
1921......	18	4,068	1,398	5,466
1922......	24	4,566	2,039	6,605
1923......	20	6,459	604	7,063
Total...	486	96,817	41,012	137,829

Publications Authorized and Issued during the Year.

The publication of 20 volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of $65,800. The following list gives the titles and names of authors of the publications issued; it includes 20 volumes, with an aggregate of 6,459 octavo pages and 604 quarto pages. Eleven additional volumes are now in press.

LIST OF PUBLICATIONS ISSUED BY CARNEGIE INSTITUTION OF WASHINGTON DURING THE YEAR ENDING OCTOBER 31, 1923.

Year Book, No. 21, 1922. Octavo, xxii+414 pages, 1 plate, 6 figures.

Index Medicus, Third Series. Vol. 2, 1922. Octavo, 1,182 pages.

No. 248. Britton, N. L., and J. N. Rose. The Cactaceæ. Descriptions and Illustrations of Plants of the Cactus Family. Quarto. In 4 volumes. Vol. IV, pages 1 to 80.

No. 256. Dickson, L. E. History of the Theory of Numbers. Vol. III. Quadratic and Higher Forms. Octavo. v+313 pages.

No. 262. Bergen, Henry. The Fall of Princes, by John Lydgate, Edited from the best Manuscripts, with Bibliographical Introduction, Notes, and Glossary. Octavo. In 4 volumes. Part I, Books I and II, pages lxv+328, 1 fig.; Part II, Books III-V, pages 329–673; Part III, Books VI-IX, pages 675–1,044, 2 figures.

No. 277. Contributions to Embryology. Nos. 65 to 71. Vol. XIV. Quarto. iii+162 pages. This book contains the following papers:

Sabin, F. R.—Direct Growth of Veins by Sprouting. (Contribution No. 65.) 10 pages, 1 plate.

Buell, C. E.—Origin of the Pulmonic Vessels in the Chick. (Contribution No. 66.) 16 pages, 2 plates.

No. 277—*continued.*

Doan, Charles A.—The Circulation of the Bone Marrow. (Contribution No. 67.) 19 pages, 1 plate, 3 text-figures.

Congdon, E. G.—Transformation of the Aortic-Arch System during the Development of the Human Embryo. (Contribution No. 68.) 64 pages, 3 plates, 28 text-figures.

Streeter, George L.—Development of the Auricle in the Human Embryo. (Contribution No. 69.) 28 pages, 6 plates, 8 text-figures.

Woollard, H. H.—The Development of the Principal Arterial Stems in the Forelimb of the Pig. (Contribution No. 70.) 16 pages, 2 plates.

Finley, Ellen B.—Development of the Subcutaneous Vascular Plexus in the Head of the Human Embryo. (Contribution No. 71.) 7 pages, 2 plates, 2 text-figures.

No. 299. Burnett, E. C. Letters of Members of the Continental Congress. Vol. II: July 5, 1776, to December 31, 1777. Octavo. xxxviii+638 pages.

No. 310. Barus, Carl. Interferometer Experiments in Acoustics and Gravitation. Part II. Octavo, viii+113 pages, 169 figures.

No. 312. Papers from the Department of Marine Biology of the Carnegie Institution of Washington. Vol. XVII. Octavo, vi+181 pp., 11 pls., 140 figs.

This book contains the following papers:

Tennent, David H.—Studies of the Hybridization of Echinoids. 42 pages, 3 plates, 28 figures.

Harvey, E. Newton.—The Production of Light by the Fishes *Photoblepharon* and *Anomalops.* 18 pages.

Mayor, Alfred G.—Hydrogen-ion Concentration and Electrical Conductivity of the Surface Water of the Atlantic and Pacific. 26 pages, 3 charts.

Wells, Roger C.—The Carbon-Dioxide Content of Sea-Water at Tortugas, Florida. 8 pages, 1 figure.

Phillips, Alexander H.—Analytical Search for Metals in Tortugas Marine Organisms. 6 pages.

Mayor, Alfred G.—Tracking Instinct in a Tortugas Ant. 8 pages.

Fowler, Henry W., and Charles F. Silvester.—A Collection of Fishes from Samoa. 18 pages, 2 figures.

Treadwell, A. L.—Leodicidæ from Fiji and Samoa. 44 pages, 8 plates, 68 figures.

Treadwell, A. L.—Polychætous Annelids collected at Friday Harbor, Washington, in February and March, 1920. 12 pages, 37 figures.

No. 322. Hay, Oliver P. The Pleistocene of North America and its Vertebrated Animals from the States East of the Mississippi River and from the Canadian Provinces East of Longitude 95°. Octavo, 507 pages, 41 maps, 25 text-figures.

No. 323. Joslin, E. P. Diabetic Metabolism with High and Low Diets. Octavo, VIII+334 pages.

No. 324. Benedict, Francis G., and Ernest G. Ritzman. Undernutrition in Steers: Its Relation to Metabolism, Digestion, and Subsequent Realimentation. Octavo, viii+333 pages, 42 figures.

No. 325. Spoehr, H. A., and J. M. McGee. Studies in Plant Respiration and Photosynthesis. Octavo, iv+98 pages.

No. 326. Hall, Harvey M., and Frederic E. Clements. The Phylogenetic Method in Taxonomy: A Monograph of the North American Species of *Artemisia, Chrysothamnus,* and *Atriplex.* Quarto, iv+355 pages, 58 plates, 47 figures.

No. 327. Bridges, C. B., and T. H. Morgan. The Third Chromosome Group of Mutant Characters of *Drosophila melanogaster.* Octavo, x+251 pages, 3 plates, 37 figs.

No. 328. Metz, Charles W., Mildred S. Moses, and Eleanor D. Mason. Genetic Studies on *Drosophila virilis,* with Considerations on the Genetics of other Species of *Drosophila.* (Paper No. 34, Department of Genetics.) Octavo, 94 pages, 5 plates, 17 figures.

No. 330. Hackett, C. W. Historical Documents relating to New Mexico, Nueva Vizcaya, and Approaches thereto, 1538-1773. Collected by Adolph F. A. Bandelier and Fanny R. Bandelier. Vol. 1, Octavo, xx+502 pages.

No. 336. Clements, Frederic E., and Frances L. Long. Experimental Pollination. An Outline of the Ecology of Flowers and Insects. Octavo, vii+274 pages.

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REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

Gentlemen: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for fiscal year ending October 31, 1923.

During this year the Executive Committee held seven meetings, printed reports of which have been mailed to each Trustee.

Upon adjournment of the meeting of the Board of Trustees of December 15, 1922, the members of the Executive Committee met and organized by the election of Mr. Root as Chairman for 1923, and by voting that the Administrative Secretary of the Institution act as secretary of the Committee for the same period.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1922–1923, together with itemized financial statements for the same period and a summary of receipts and expenditures of the Institution to date. The President also submits a report and outline of suggested appropriations for the year 1924. The Executive Committee hereby approves the report and recommendations of the President, upon the basis of which additional recommendations respecting appropriations for the year 1924 were authorized by the Committee at its meeting of this date.

The Board of Trustees, at its meeting of December 15, 1922, appointed the American Audit Company to audit the accounts of the Institution for the fiscal year ending October 31, 1923. The report of the auditor, including a balance-sheet showing the assets and liabilities of the Institution on October 31, 1923, is herewith submitted as a part of the report of the Executive Committee.

There is also submitted a statement of receipts and disbursements since the organization of the Institution on January 28, 1902.

No vacancies exist in the membership of the Board of Trustees. The tenures of office of Mr. Henry White and Mr. John J. Carty as members of the Executive Committee terminate at the coming annual meeting.

Elihu Root, *Chairman.*
John J. Carty.
W. Cameron Forbes.
John C. Merriam.
Wm. Barclay Parsons.
Stewart Paton.
Henry S. Pritchett.
Henry White.

December 13, 1923.

Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1923.

RECEIPTS.		
Interest:		
Endowment	a$19,057,853.12	
Reserve Fund (Cr. to R. F.)	631,661.31	
Reserve Fund (Cr. to Income)	412,984.47	
Insurance Fund	112,051.92	
Colburn Fund (Cr. C. F.)	26,822.14	
Colburn Fund (Cr. to Income)	9,336.97	
Pension Fund	26,106.38	
		$20,276,816.31
Colburn Fund		52,015.74
Sales of Publications:		
Index Medicus	91,581.56	
Year Book	1,247.61	
Miscellaneous	121,360.85	
		214,190.02
Revertments:		
Grants	187,905.40	
Administration	11,716.53	
Unappropriated Fund	22,475.80	
General Contingent Fund	5.25	
		222,102.98
Miscellaneous:		
Carnegie Corporation of N. Y.		
C. I. of W. ....$750,000.		
National Research C.. 150,000.		
Special .... 60,000.		
	960,000.00	
Insurance Fund	6,694.85	
Pension Fund	12,687.69	
Sale of paper	6,613.25	
		985,995.79
Redemption and Sale of Bonds		3,131,642.22
		24,882,763.06

DISBURSEMENTS.		
Investment:		
Securities	$6,843,332.48	
Collection charges	9,008.82	
Administration building and site	309,915.69	
		$7,162,256.99
Pension Fund		125,014.52
Insurance		24,770.94
Grants:		
Large	12,470,848.56	
Minor	2,439,203.28	
		14,910,051.84
Publication		b1,120,327.18
General Contingent Fund		2,293.88
National Research Council		150,000.00
Administration:		
Trustees	c58,640.58	
Executive Committee	37,817.36	
Advisory Committees:		
Honoraria 1902–07	11,860.00	
Travel and subsistence	4,367.41	
Salaries	634,947.76	
Shipping publications	b56,567.24	
Rent, surety, telephone	60,304.61	
Printing	bd65,872.51	
Office expenses	35,710.06	
Equipment	18,389.02	
Building and grounds, supplies, janitor, fuel, light, water	53,565.03	
Contingent	1,897.01	
Lectures and exhibits	226.00	
Organization expenses (1902)	6,991.98	1,047,156.57
		24,541,871.92
Cash in Banks		340,891.14
		24,882,763.06

a Including interest from Income and Building Fund bonds.
b Year Books and Shipping Publications carried under Administration to January 1, 1921, and thereafter under Publication.
c Travel and subsistence in connection with official meetings.
d Including Year Books published prior to January 1921.

REPORT OF AUDITORS.

WASHINGTON, D. C., *November 27, 1923.*

TO THE BOARD OF TRUSTEES,
Carnegie Institution of Washington,
Washington, D. C.

DEAR SIRS: We have audited the books and records of the Carnegie Institution of Washington for the year ended October 31, 1923. We did not audit the books of the various departments as this is done by the Bursar and Assistant Bursar.

The income from investments and other sources has been duly accounted for and disbursements were supported by proper vouchers.

We counted the cash on hand, and the cash in banks was verified with certificates from the depositaries.

The securities representing the investments were examined by us.

We certify that the balance sheet, the schedules of securities and real estate and equipment, and the statement of receipts and disbursements as shown in the regular printed financial statement of the Institution at the close of business October 31, 1923, are in accordance with the books.

Respectfully submitted,

F. W. LAFRENTZ & CO.,
Public Accountants
(Formerly The American Audit Co.)

Copies of the Financial Statement, certified by the auditor in the above report, follow on pages 36 to 40.

Balance Sheet, October 31, 1923.

ASSETS.

Investments (interest-bearing securities):			
Endowment		$22,115,189.25	
Colburn Fund		110,980.00	
Reserve Fund		3,108,799.93	
Insurance Fund		371,570.88	
Pension Fund		133,623.17	
Harriman Fund		300,000.00	
		26,140,163.23	
Cash—			
Endowment, Colburn and Reserve Funds, awaiting investment	$23,401.22		
Insurance Fund, for current purposes	23,880.64		
Pension Fund, for current purposes	23,742.92		
		71,024.78	
			$26,211,188.01
Property Account:			
Real Estate and Equipment at original cost—			
Division of Administration		340,315.69	
Departments of Research		2,972,275.27	
			3,312,590.96
			29,523,778.97
Current Assets:			
Cash—			
In banks	269,866.36		
Petty cash and stamps	400.00		
		270,266.36	
Income estimated for the year 1923—			
Balance uncollected		149,603.79	
		419,870.15	
Publications and paper—			
Books on hand at sale price	294,251.03		
Printing paper in stock for future publications	14,455.06		
	308,706.09		
Outstanding accounts—			
Sundry bills for publications sold	2,056.95		
		310,763.04	
			730,633.19
			30,254,412.16

LIABILITIES.

Endowment and Other Funds:			
Endowment		$22,115,284.06	
Colburn Fund		111,666.88	
Reserve Fund		3,131,419.46	
Insurance Fund		395,451.52	
Pension Fund		157,366.09	
Harriman Fund		483,671.75	
			$26,394,859.76
Income Invested in Property			3,128,919.21
			29,523,778.97
Current Liabilities:			
Large Grants	$177,193.78		
Minor Grants	85,326.71		
Publications	70,253.12		
Administration	17,457.79		
		350,231.40	
General Contingent Fund		8,161.24	
Unappropriated Balance		61,477.51	
			419,870.15
Value of publications, paper and invoices			310,763.04
			30,254,412.16

Receipts and Disbursements for the Year Ending October 31, 1923.

RECEIPTS.

Interest from:		
Endowment—		
Bonds	$1,114,541.13	
Bank balance	7,204.86	
		$1,121,745.99
Reserve Fund—		
Bonds	152,424.33	
Bank balance	611.50	
		153,035.83
Insurance Fund—		
Bonds	16,740.78	
Bank balance	572.54	
		17,313.32
Colburn Fund—		
Bonds	5,596.36	
Bank balance	196.84	
		5,793.20
Pension Fund—		
Bonds	8,370.26	
Bank balance	570.25	
		8,940.51
Sales of Publications:		
Index Medicus	5,777.46	
Year Book	70.10	
Miscellaneous Books	7,994.20	
		13,841.76
Revertments:		
Large Grants	3,289.07	
Minor Grants	5,486.02	
Publication	593.32	
Administration	305.25	
Unappropriated Fund	60.26	
General Contingent Fund	5.25	
		9,739.17
Redemption and Sale of Securities	....	1,686,032.85
Miscellaneous:		
Carnegie Corp. of N. Y.	30,000.00	
Pension Fund	4,719.25	
Sale of paper	56.80	
		34,776.05
		3,051,218.68
Balance, Oct. 31, 1922	....	320,846.34
		3,372,065.02

DISBURSEMENTS.

Investment:		
Securities	$1,715,338.99	
Collection Charges	198.73	
		$1,715,537.72
Pension Fund:		
Annuity contribution	....	35,781.64
Grants:		
Large	930,395.95	
Minor	194,269.17	
		1,124,665.12
Publication:		
General publication	68,400.75	
Catalogues, etc.	1,988.48	
Shipping expenses	6,845.80	
Division of publications	12,167.03	
		89,402.06
General Contingent Fund	....	2,293.88
Administration:		
Trustees	3,818.61	
Executive Committee	3,854.48	
Salaries	42,520.27	
Surety, postage, telephone, telegraph	1,911.89	
Printing	1,588.59	
Office expenses	1,989.13	
Equipment	724.63	
Building and grounds—		
Supplies, janitor, fuel, light, water	6,420.77	
Lectures and exhibits	226.00	
Contingent	439.09	
		63,493.46
		3,031,173.88
Cash in Banks:		
Uninvested Principal—		
Endowment	94.81	
Reserve Fund	22,619.53	
Colburn Fund	686.88	
Pension Fund	23,742.92	
Insurance Fund	23,880.64	
	71,024.78	
Investment Accounts	269,866.36	
		340,891.14
		3,372,065.02

Schedule of Securities.

SECURITIES.	Par Value.	Market Value Oct. 31, 1923.	Cost or Value at date acquired.
Endowment.			
U. S. Steel reg. 5s 1951, Series A, B, C, D, E, F.	$21,200,000	$22,154,000.00	$21,200,000.00
Am. Smelt. and Ref. Co. 1st 5s 1947	25,000	22,812.50	22,787.50
Cedar Rapids Mfg. and P. Co. 1st sink. 5s 1953	25,000	23,500.00	24,253.60
C. M. & Pug. Sd. 4s 1949	175,000	87,937.50	159,268.00
C. M. & St. P. gen. 4½s 1989	14,000	10,920.00	13,953.75
Chi. U. Station 1st 6½s 1963	25,000	28,468.75	28,656.25
Cleveland U. Terminal 1st sink. 5½s 1972	25,000	25,625.00	25,843.75
Commonwealth Edison Co. 1st 5s 1943	16,000	15,300.00	15,695.00
Dom. of Canada 5s 1952	50,000	49,875.00	49,500.00
Lehigh and L. E. 4½s 1957	325,000	279,500.00	331,568.30
N. Y. Gas & E. L. H. & P. Co. 4s 1949	8,000	6,560.00	6,559.50
Province of Ontario 5½s 1937	25,000	25,125.00	25,508.60
South and No. Ala. con. 5s 1936	150,000	148,500.00	160,875.00
So. Ry. Co. 1st con. 5s 1994	25,000	23,781.25	23,937.50
Standard Oil of N. Y. deb. 6½s 1933	25,000	26,468.75	26,787.50
			22,115,189.25
Colburn Fund.			
C. M. and St. P. gen. 4½s 1989	4,000	3,120.00	4,070.00
Cleveland U. Terminal Co. 1st sink. 5½s 1972	10,000	10,250.00	10,300.00
Liggett & Myers Tob. Co., 7s 1944	10,000	11,650.00	11,600.00
P. Lorillard Co. 7s 1944	10,000	11,700.00	11,497.50
Ore. Short Line con. 1st 5s 1946	4,000	4,080.00	3,910.00
Ore. Wash. Ry. and N. Co. 1st ref. 4s 1961	10,000	7,987.50	7,940.00
Park & Tilford Co , sink. deb. 6s 1936	8,000	6,880.00	6,400.00
Penna. R. R. Co., gen. 4½s 1965	50,000	45,375.00	51,062.50
Pitts. Shawmut and Nor. 4s 1952	42,000	4,200.00	4,200.00
			110,980.00
Harriman Fund.			
So. Pac. S. F. Ter. 4s 1950	100,000	81,250.00	100,000.00
C. B. and Q., Ill. Div. 4s 1949	200,000	176,500.00	200,000.00
			300,000.00
Insurance Fund.			
Am. Smelt. and Ref. Co. 1st 5s 1947	10,000	9,125.00	9,002.50
A. T. and S. Fe. gen. 4s 1995	50,000	44,750.00	50,056.25
Bell Tel. of Canada, deb. 5s 1925	25,000	24,375.00	24,775.84
C. B. and Q. gen. 4s 1958	30,000	25,725.00	28,237.50
C. M. and St P. gen. 4½s 1989	1,000	780.00	995.00
Consumers Power Co. 1st ref. 5s 1936	25,000	23,625.00	23,812.50
Dom. of Canada 5s 1952	25,000	24,937.50	24,727.50
Great Nor. 1st ref. 4¼s 1961	21,000	18,060.00	20,944.00
Ill. Central ref. 4s 1955	21,000	17,850.00	19,008.75
Missouri, Kansas and Texas 1st 4s 1990	25,000	18,625.00	19,366.67
New England Tel. & Tel. 5s 1952	12,000	11,730.00	11,934.25
Nor. Pac. ref. and imp. 6s 2047	5,000	5,175.00	5,431.25
Ore. Wash. Ry. and N. Co. 1st ref. 4s 1961	25,000	19,968.75	19,881.25
Ore. Short Line con. 1st 5s 1946	25,000	25,500.00	24,468.25
Penna. R. R. con. 4½s 1960	24,000	22,800.00	25,095.01
Standard Oil Co. of N. Y. deb. 6½s 1933	5,000	5,293.75	5,311.25
So. Ry. Co. 1st con. 5s 1994	25,000	23,381.25	23,843.75
City of Toronto con. deb. 5s 1949	25,000	23,625.00	24,039.36
U. S. A. Fourth L. L. con. 4¼s	3,000	2,917.50	3,000.00
Wis. Central Ry. Co. 1st gen. 4s 1949	10,000	7,675.00	7,640.00
			371,570.88
Carried forward	22,953,000	23,647,285.00	22,897,740.13

Schedule of Securities—continued.

SECURITIES.	Par Value.	Market Value Oct. 31, 1923.	Cost or Value at date acquired
Brought forward	$22,953,000	$23,647,285.00	$22,897,740.13
Reserve Fund.			
Am. Smelt. and Ref. Co. 1st 5s 1947	15,000	13,687.50	$13,510.00
Am. Tel. & Tel. Co., col. 4s 1929	50,000	46,312.50	45,500.00
B. & O. R. R. Co., gen. and ref. 5s 1995	100,000	83,750.00	102,375.00
Canada So. Ry. Co. con. 5s 1962	40,000	39,300.00	39,231.50
Cedar Rapids Mfg. and P. Co. 1st sink. 5s 1953	25,000	23,500.00	24,025.00
Central Pacific, 1st ref. 4s 1949	50,000	43,437.50	48,250.00
C. B. and Q. gen. 4s 1958	150,000	128,625.00	141,263.75
C. M. and St. P. gen. 4½s 1989	15,000	11,700.00	14,925.00
Chi. and N. W. gen. 3½s 1987	120,000	85,350.00	100,300.00
Chi. U. Station 6½s 1963	75,000	85,406.25	85,610.25
Cleveland U. Terminal Co. 1st sink. 5½s 1972	5,000	5,125.00	5,153.75
Commonwealth Edison Co. 5s 1943	36,000	34,425.00	35,345.25
Consumers Pow. Co. 1st ref. 5s 1936	25,000	23,625.00	23,878.50
Dominion of Canada 5s 1952	100,000	99,750.00	98,936.25
General Electric, deb. 5s 1952	155,000	157,325.00	158,213.47
Great Nor. 1st ref. 4¼s 1961	48,000	43,128.00	48,109.25
Illinois Central R. R. Co., ref. 4s 1955	100,000	85,000.00	89,668.75
Int. Rap. Trans. ref. 5s 1966	280,000	165,200.00	276,701.00
Kansas City Terminal Ry. Co. 1st 4s 1960	50,000	41,000.00	40,520.00
Lake Shore and M. S. 4s 1928	50,000	47,250.00	47,000.00
Liggett and Myers Tob. Co. 7s 1944	98,000	114,170.00	116,083.27
Long Island ref. 4s 1949	50,000	39,187.50	48,285.00
P. Lorillard Co. 7s 1944	29,000	33,930.00	33,957.00
Missouri, Kansas & Texas 1st 4s 1990	50,000	37,250.00	38,661.67
City of Montreal 5s 1956	25,000	23,750.00	24,062.50
City of Montreal Sinking 5s 1954	75,000	71,250.00	72,375.00
New England Tel. & Tel. 5s 1952	30,000	29,325.00	29,858.75
N. Y. W. and Boston 1st 4½s 1946	50,000	18,500.00	49,187.50
N. Y. Gas & E. L. H. & P. Co. 4s 1949	18,000	14,760.00	14,927.00
Nor. Pac. ref. and imp. 6s 2047	95,000	98,325.00	96,756.25
Nor. Pac. gen. lien 3s 2047	50,000	29,125.00	33,101.25
Province of Ontario deb. 5½s 1937	35,000	35,100.00	35,787.50
Province of Ontario deb. 6s 1943	40,000	42,400.00	43,137.50
Ore. Short Line con. 1st 5s 1946	2,000	2,040.00	1,955.00
Ore.-Wash. Ry. and N. Co. 1st and ref. 4s 1961	50,000	39,937.50	46,375.00
Penna. R. R. Co., gen. 4½s 1965	30,000	27,225.00	29,837.50
Penna. R. R. Co. con. 4½s 1960	101,000	95,950.00	105,608.12
Southern Pacific 1st ref. 4s 1955	100,000	87,000.00	92,148.75
So. Rwy. Co. 1st con. 5s 1994	50,000	47,562.50	47,875.00
Standard Oil of N. Y. deb. 6½s 1933	70,000	74,112.50	74,504.75
City of Toronto con. deb. 5s 1949	75,000	70,875.00	72,118.10
Union Pac. 1st ref. 4s 2008	140,000	115,850.00	128,722.50
U. S. A. Fourth of 1917—2nd conv	347,000	337,437.50	340,181.30
City of Winnipeg, interim deb. 5s 1943	50,000	49,000.00	48,250.00
City of Winnipeg, deb. 6s 1946	15,000	16,050.00	16,050.00
Wis. Central Ry. Co. 1st gen. 4s 1949	40,000	30,477.00	30,477.00
			3,108,799.93
Pension Fund.			
Canada So. Ry. Co. con. guaranteed 5s 1962	10,000	9,825.00	9,790.00
Cleveland U. Terminal Co. 1st sink. 5½s 1972	10,000	10,250.00	10,315.00
Dominion of Canada 5s 1952	25,000	24,937.50	24,727.50
Liggett & Myers Tob. Co. 7s 1944	2,000	2,330.00	2,375.50
P. Lorillard Co. 7s 1944	5,000	5,850.00	5,863.75
Missouri, Kansas & Texas 1st 4s 1990	25,000	18,625.00	19,396.67
New England Tel. & Tel. 5s 1952	10,000	9,775.00	9,955.00
N. Y. Gas E. & L. H. & P. Co. 4s 1949	24,000	19,680.00	19,693.50
Oregon Short Line con. 1st 5s 1946	20,000	20,400.00	19,550.00
Ore.-Wash. Ry. and N. Co. 1st ref. 4s 1961	15,000	11,981.25	11,956.25
	26,303.000	26,624,425.00	133,623.17
Grand total			26,140,163.23

Real Estate and Equipment, Original Cost.

Administration:		
Building, site, and equipment		$340,315.69
Laboratory for Plant Physiology (September 30, 1923):		
Buildings and grounds	$54,705.41	
Laboratory and library	28,362.65	
Operating appliances	11,863.28	
		94,931.34
Ecological Research (December 31, 1921):		
Building, Laboratory	4,547.00	
Library, Operating	2,069.88	
		6,616.88
Department of Embryology (September 30, 1923):		
Library	1,203.15	
Laboratory	7,351.13	
Administration	3,846.93	
		12,401.21
Department of Genetics (September 30, 1923):		
Buildings, grounds, field	265,153.15	
Operating	19,629.13	
Laboratory apparatus	11,950.12	
Library	22,290.71	
Archives	45,488.90	
		364,512.01
Geophysical Laboratory (September 30, 1923):		
Building, library, operating appliances	189,782.61	
Laboratory apparatus	92,446.29	
Shop equipment	11,197.73	
		293,426.63
Department of Historical Research (September 30, 1923):		
Office	3,138.92	
Library	4,537.13	
		7,676.05
Department of Marine Biology (September 30, 1922):		
Vessels	30,930.43	
Buildings, docks, furniture, and library	12,130.86	
Apparatus and instruments	9,322.55	
		52,383.84
Department of Meridian Astrometry (September 30, 1923):		
Apparatus and instruments	3,257.34	
Operating	3,560.60	
		6,817.94
Nutrition Laboratory (September 30, 1923):		
Building, office, and shop	124,083.83	
Laboratory apparatus	26,972.28	
		151,056.11
Mount Wilson Observatory (August 31, 1923):		
Buildings, grounds, road, and telephone line	197,207.27	
Shop equipment	39,354.53	
Instruments	497,870.66	
Furniture and operating appliances	162,432.71	
Hooker 100-inch reflector	597,448.87	
		1,494,314.04
Department of Terrestrial Magnetism (September 30, 1923):		
Building, site, and office	205,643.66	
Vessel and survey equipment	173,248.26	
Instruments, laboratory, and shop equipment	109,247.30	
		488,139.22
		3,312,590.96

REPORTS ON INVESTIGATIONS AND PROJECTS

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1923, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

LABORATORY FOR PLANT PHYSIOLOGY.[1]

D. T. MacDougal, Director.

The activities of the members of the staff have been devoted to three main subjects—photosynthesis and metabolism, permeability and growth, and to certain ecological relations of plants. Progress has been made in the study of some of the special problems as described in the following paragraphs.

GROWTH AND PERMEABILITY.

Dendrographic Records of Growth in Trees, by D. T. MacDougal.

The series of observations on the course of growth in the trunks of trees, which was begun with the first design of the dendrograph in 1918, has been continued and records amounting to 20 seasons have been secured, making a total available of about 90 seasons, the greatest number being of the Monterey pine, one tree of which has furnished a continuous record for 5 years.

The general behavior of the Monterey pine now being fairly apprehended, many series of experiments have been begun which may yield evidence upon the mechanism of transport of material and of physical action in growth. Girdling, defoliation, decapitation, injections of material, and increase and decrease of pressures have all been used with some decisive results which will be presented in forthcoming publications.

The dendrographic results in connection with the measurements of trunks made by Dr. Shreve as described in a separate paragraph establish the fact that the thickness of the layer of wood formed in the Monterey pine does not correspond directly with the rainfall of the season of its formation, of the previous season, or of any known phase of such precipitation. The amount of wood formation is therefore not a direct record of rainfall in this tree and should not be assumed to be in any tree until it has been proved to be such an index. Extended study of cross-sections of the trunks of the yellow pine supports the conclusion that in this tree the amount of wood formed in any year does show a fairly close correspondence to the amount of precipitation.

Formation of wood, and growth in general, is the result of the integrated or correlated action of several factors, including soil moisture, temperature, light, and food-supply. In some species water may be the dominant agency, and high precipitation in the habitats of these species may be connected with optimum intensities of the other contributory factors. On the other hand, it is doubtless true that in some regions the season with the most rainfall may have unfavorable conditions in other respects. Something of this kind seems to be the case with the Monterey pine. Six seasons' records of the redwood (*Sequoia sempervirens*) have been made, and it seems advisable to extend the observations under experimental conditions to ascertain the influence of the amount of precipitation as well as other features upon the amount of growth. The course and localization of growth in a girdled tree have been followed from the time of operation until its death, 14 months later.

The woody cylinder of a living tree has been found to show a daily variation in diameter amounting to 1 part in 1,550 in March, which decreased to 1 part in 3,200 a month later, and then rose in midsummer to 1 part in 2,500. The trunk of a dead tree does not show such variations of a magnitude within the range of the instruments.

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[1] Reorganized Department of Botanical Research, approved by Executive Committee May 18, 1923. Situated at Tucson, Arizona, and Carmel, California.

Defoliation of the Monterey pine early in the season caused a stoppage of growth, while such defoliation in June had but little effect. Decapitation of the trunk within a meter of the dendrograph caused a stoppage of growth, although the stump bore many active leafy branches. These and other experimental tests are being extended and repeated before interpretations of their effect on the mechanism of food transport are attempted.

Young trees of the Monterey pine, growing near the Coastal Laboratory, which exhibited interrupted impulses in enlargement of the trunks in December, began growth more steadily in the first week in January and continued in the cases of Nos. 16, 17, and 20 until the end of October. The period of growth thus exemplified amounted to about 300 days, which is the longest yet recorded for any tree of which an accurate record has ever been made. The common conception that trees in the tropics are actively growing throughout the year has not been confirmed nor adequately tested.

By the cooperation of Mr. G. A. Pearson, of the Forest Experiment Station at Fort Valley, near Flagstaff, Arizona, dendrographs have been operated on two trees of *Pinus scopulorum* at an elevation of about 7,000 feet. The behavior of the yellow pine has thus been followed on the slopes of Pike's Peak in Colorado, on the crest of the Santa Catalina Mountains in Arizona, and on this elevated plateau at the place noted. These results have a special interest, since trunks of this pine are being used as records of climate in studies of the remains of the peoples who inhabited the region during the last 1,000 or 2,000 years.

Stem Analysis of Monterey Pine and Redwood, by Forrest Shreve.

The records embodied in the annual rings of trees form excellent material for investigating the relation of environmental conditions to the yearly march of growth. The use of the records of certain long-lived trees as criteria for interpreting the climatic conditions of the remote past makes it important to determine the influence exerted upon growth by the conditions of the more recent past, for which we have climatological records. These considerations have led to a continuation of work on the Monterey pine and redwood in the vicinity of the Coastal Laboratory.

Further work, including the bisection and detailed measurement of the trunk of a second pine, has shown a very close correspondence between the course of the growth graph based on stump measurements and that based on the average of 10 transverse sections in the lowest 30 feet of the trunk. This strengthens the reliability of data from the stump section alone as a criterion of the performance of the trunk as a whole.

The course of growth has been measured for 6 small trees and 4 large ones growing under identical conditions in close proximity to the rainfall station at Carmel. The trees in each group were selected for similarity of size and crown development, those in the small group still having the excurrent crown indicative of active growth. In these trees growth was correlated with the rainfall for December to September, inclusive, a period which covers the growing-season of the pine and one preceding month. Correlations were made from graphs of growth and rainfall and were regarded as positive in cases where both rose or fell together. Out of 19 years, in only 5 years were all 6 of the trees in agreement *inter se* and with the rainfall. In one year the trees were all in agreement, but did not agree with the rainfall. There were only three additional years in which 5 of the 6 trees were in agreement. Out of 108 possible agreements for the 6 trees, there were only 68 actual agreements, indicating a percentage correlation of 62.9. In the case of the 4 large trees this percentage was 50.9. These figures indicate a very weak influence of rain upon growth in young trees, and none in mature trees. A comparison has been made of the growth of the above-mentioned trees in the four wettest and the two driest years in the last 25 years. For the small trees the average wood increment in the wet years was 4.3 mm., in the dry years 2.6 mm., but in the large trees the increments were 6.1 mm. in the wet years and 7.6 mm. in the dry years. The amounts of growth per inch of rainfall in the small trees are about twice as great in the dry years as in the wet, and in the large trees nearly four times as great in the dry years as in the wet. This indicates that, whatever qualitative correlation there may be between growth and rainfall, there is a pronounced lack of any quantitative relation between the amount of growth and the amount of rain in a given year.

In the years 1912 and 1921 the seasonal rainfall was nearly the same (13.38 inches and 13.97 inches, respectively). The average amounts of growth in the two years were 3.2 mm. and 2.6 mm., respectively, for the small trees and 4.22 mm. and 4.30 mm. for the large trees. In order to evaluate the influence of temperature on growth in these years with nearly the same rainfall, summations of all temperatures above 40° F. were made, covering the months of active growth (January to April) and the entire growing-season (January to September), and based on the thermograph records taken at the Coastal Laboratory. For the period of active growth the totals are 28,253 hour-degrees for 1912 and 30,261 hour-degrees for 1921. For the growing season the figures are 92,950 hour-degrees for 1912 and 94,969 hour-degrees for 1921. These small differences between the two years are in agreement with the very small difference between the growth of the 4 large trees and in disagreement with the amounts of growth in the 6 young trees. These preliminary data afford some evidence that rainfall is of greater importance than temperature in the growth of young trees, and that temperature is of greater importance than rainfall in the case of mature trees. It is at least apparent that in the Monterey pine, growing in its native coastal habitat, there is no evidence that rainfall is a dominant and constant condition determining the annual increment of woody tissue.

Growth as a Problem in Permeability, by D. T. MacDougal.

The cell of the plant in its earliest stage is a "solid" unit of colloidal material which increases by the formation of new particles or ions of substances such as pentosans, albumins, lipins, or soaps within its mass. This accretion stage, as I have termed it, does not account for more than a small fraction of the total volume of the plant or tissue. The greater part of the expansion or measurable growth of the plant is due to the distention or ballooning of the cells. Spaces or cavities are formed within the protoplasm, and these are enlarged by the pressure of the water which is drawn into them by the osmotic action of the sugars and other organic compounds which are constantly being formed in the protoplasm of living cells and in part by the mineral salts which have penetrated to these vacuoles. If the plant cell were a simple osmometer, the problems of enlargement would be simple; but being a living mechanism, all of its parts are in a state of continual change.

Our present knowledge of permeability rests chiefly upon experiments upon the eggs of fishes, starfish, and other marine organisms, on vegetative cells of algæ, and upon the tissues of a few higher plants. The animal eggs used are of a type in which the passage of material into and out of the cell is controlled by a thin external membrane. This membrane is variously taken to be a protein, a lecitho-protein, or a protein-lipin-soap combination by various observers.

The importance of permeability is very great in the relations of the plant to the soil as carried out by root-hairs, these structures being the tubular extension of epidermal cells on the young and actively growing part of the root, although they sometimes persist and are active for 70 or 80 days. All exchanges between the soil and the medium must take place through these cells. The root-hair is at first a dense mass of protoplasm limited by a fairly definite membrane, but its development quickly carries it to a stage in which the interior is occupied by an enormous vacuole, while the protoplasm forms a thin layer lying against the wall. Permeability here becomes a question of the passage of material through both wall and protoplasm. The entire thickness of the wall and of the layers of protoplasm which intervene between the vacuole and the outside of the cell is to be taken into account in all studies of growth in which at no stage can the wall be considered as dead, or as anything but a colloid, the mesh or lattice of which may be altered by many factors.

The wall, outside of its lipoidal component, in the stage in which it is a control of permeability, has a skeletal structure of cellulose, swelling slightly in water but entirely insoluble. A mixture of lipins, manosans, glucosans, and pectins, all liquefying or going into solution in water, occupies the spaces of mesh-work. Pectates tend to accumulate in the middle portion of the wall between joined cells stratifying as a middle lamella. In the case of a root-hair, this material forms the external part of the wall.

Measurement of Changes due to Hydration of Colloids, to Altered Permeability, and to Growth, by D. T. MacDougal.

Determinations of permeability have been made by a wide variety of methods, including the study of visible and micro-chemical changes in the cell, analysis of sap and of the medium, measurement of hydrogen-ion concentration in the sap and in the external solution, measurements of the electrical conductivity of the cell and of the medium, estimations of metabolism, plasmolysis, plasmometry, measurements of tissue tensions, and of diffusion, and finally by measurements of changes in weight and volume of living cell-masses induced by the entrance or loss of water and of other substances.

In my own studies, determinations of the action of various substances upon the swelling of biocolloids and upon living and dead tissues have been made by identical technique with the auxograph designed for this purpose.[1] The composition of the living material has been made the subject of extensive inquiries in this laboratory, and the information thus made available has had no little value in the present connection.

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[1] H. A. Spoehr, Carbohydrate economy of the cacti. Carnegie Inst. Wash. Pub. No. 297, 1919.

Estimation of the concentration and ionization of immersion liquids and of the cell-sap of sections has been made by the conductivity method. The use of the artificial cell made it possible to determine the osmotic action of the contents, the amount of exosmose of the organic contents, and by conductivity tests the amount of the electrolytes lost from the immersion liquids to be absorbed or combined with the material of the external layers or diffused into the cell contents.

The widely divergent suites of data that may be secured by the hydration of material from different plants suggest varying composition of the cell. It was therefore arranged that artificial cells should be constructed which should show the action of different colloids in the external layers. Relative permeability is taken to be denoted by the outflow from cells immersed in various solutions. Such data are also supported by determinations of the resistance or conductivity of the immersion liquids or of the cell contents to ascertain the behavior of the electrolytes which may have passed into the cell, been absorbed by the colloids, or combined with some of the material of the external layer. Estimations were also made of the exosmosis of the organic material from the cell contents.

The design of this cell was described in the annual report of this Department for 1922.

Effect of Salt Solutions on Hydration and Swelling of Plant Tissues, by F. T. McLean.

The study of the swelling of plant tissues in salt solutions, previously reported, was continued. This year's results indicate that the difference in the behavior of stem tips of walnut (*Juglans major*) and of blackberry (*Rubus vitifolius*), noted last year, was due to the manner of preparation of the material for testing. The walnut stem tips were sufficiently large so that each tip could be bisected lengthwise. The halves, with the epidermis on, were placed upright in the glass dishes, and their lengthwise swelling in different test solutions was recorded by auxographs. Thus one half of each tip was used for a test in salt and the other was swelled in distilled water for a control. With this treatment, the swelling was greatest in calcium chloride, less in magnesium, and least in sodium and potassium chlorides. The blackberry tips were so small that each one was used entire, and, in order to secure good penetration of the solutions into the tissues, each tip was scraped free of pubescence, one side was sliced off a little, the sections were placed in the dishes and subsequently treated as with walnut. By this treatment most or all of the epidermis was removed from the blackberry sections. When so treated, swelling was greatest in potassium chloride, less in sodium and calcium chlorides.

Experiments with blackberry were repeated in a similar manner this season, with indeterminate results, but generally agreeing with the previous ones (but no initial shrinkage was noted in any of the solutions). Sections of blackberry were also prepared as nearly as possible in the same manner as the previous walnut sections, i. e., the epidermis was left on them and one side of each was sliced off rather deeply; with the epidermis thus in place, the swelling of the blackberry sections in the different solutions gave results more nearly like those for walnut. The swelling was then greatest in calcium chloride, less in sodium, and least in potassium chloride. The results to date are summarized below:

Relative swelling of stem tips in salt compared to that in water as unity.

Immersion fluid.	Walnut.		Blackberry.			
	With epidermis.		With epidermis.		Without epidermis.	
	Average.	No. of tests.	Average.	No. of tests.	Average.	No. of tests.
KCl 0.01M.............	1.0	1	.9	16	1.3	14
NaCl 0.01M.............	1.0	1	1.4	15	1.1	14
CaCl 0.01M.............	1.6	1	1.2	16	1.0	14

These results indicate that the different tissues comprising the young stems do not react in the same manner to the salt solutions. Thus, with the epidermis intact around a portion of the stem, the elongation was greatest in either calcium or sodium chloride solution. After the epidermis was removed from the blackberry stems, they swelled most in potassium chloride.

There is a rather suggestive parallelism with the absorption rates by artificial cells in similar solutions. Such cells, made from paper extraction thimbles, coated with pectin and agar, hardened in alcohol, and lined with agar, absorb most rapidly from a calcium-chloride solution, least from a potassium solution, thus paralleling the results with walnut. If similar artificial cells are lined with an agar and gelatin mixture, they then absorb most rapidly from a sodium-chloride solution and least from potassium chloride, thus corresponding to the behavior of blackberry stem tips with the epidermis on. On the other hand, artificial cells prepared with an outer coating of agar alone, and lined with gelatin and agar, absorb most rapidly from a potassium-chloride solution and least rapidly from calcium chloride. This latter is, then, similar to the swelling of blackberry stem tips without the epidermis.

The epidermis on the stem tips of blackberry appears thus to exert an influence on their swelling which is strikingly similar to the effect of a pectinized outer layer on the absorbtion of the artificial cells. In the absence of the epidermis, the stem tips of blackberry appear to swell in the different solutions used in a manner parallel to the relative rates of absorption by artificial cells coated with agar alone. It is not assumed from this that the apparent similarity in behavior of artificial cells and of the cell-masses in the several tissues of the stem is necessarily caused by similar arrangements of similar cell components in each case. It is quite possible that widely different colloidal substances may react in a like manner to the series of salt solutions here dealt with; further, the mechanism in the swelling of the plant cells involves several considerations which do not enter into the operation of the artificial cells. The swelling of the plant cells requires stretching of the cell walls, and any agency which would render them more elastic might also permit greater swelling, whereas a similar action on the walls of the artificial cell would decrease the excretion from it and thus decrease the amount of apparent absorption. Nevertheless, the similarity of results by the two methods of study is certainly suggestive and, while these results are in no sense final, they indicate some of the lines of investigation which may be followed in attempting to explain diverse behavior of plant cells toward salt solutions.

Relative Effects of Common Metals in producing Contraction, Expansion, and Plasmolysis of Cell-Masses, by D. T. MacDougal.

The cell-sap of vacuolar contents, in addition to sugars, contains amino-acids and salts of the common bases, including nitrates, sulphates, and chlorides. When cells with such contents are placed in distilled water, the deficit, which may almost invariably be recognized, is taken up by the entrance of water with a consequent increase in volume. If, now, salts be added to the water in a similar experiment, the permeability of the wall will be affected by the action of these salts in forming compounds with the material in the layers of cell material, the solution out of some of the material, and the colloidal action of the kations and anions on the colloidal aggregates of the wall and plasma. The result may be an increase or a contraction of the cell, according to conditions. The diffusion of the ions into the cell will be mainly determined by their ionic mobility, which in the common bases will be as K 64.7, Na 43.6, Ca 51.8. Their action in aggregating effects will be in proportion to the residual charges they carry, which will be in the above order, but with the least effect by potassium and the greatest by calcium.

Now, when cell-masses which have been fully hydrated in water are placed in a salt solution which is isotonic or slightly hypertonic to the cell-sap, it is found that a contraction ensues which continues for a short time, after which expansion takes place, which does not, however, carry the cell to the volume which it had when fully hydrated in distilled water. The proportion of the contraction which is regained is taken by Kahho to indicate the degree of change which has been produced in the permeability of the cell. Thus NaCl at 0.0141M gave a resumption of 29 to 30 per cent, at 0.181M gave 35 to 54 per cent, while roots in $CaCl_2$ at 0.134M showed no return toward the original dimensions. These solutions being isotonic, Kahho concludes that the penetrability of the potassium is greatest, but that the permeability is lessened most by the calcium, with the action of the sodium lying between.

It was important that these tests should be repeated with other material. Joints of *Opuntia* were chosen for this purpose. Living sections of this material, which were in a condition in which they would swell 150 to 160 per cent in thickness in pure water, were placed under the auxograph in water, and after 6 to 9 hours, when the increases amounted to 120 to 130 per cent, the water in the immersion dishes was replaced with graduated series of potassium, sodium, and calcium chlorides.

This method of auxographic measurement not only enables the observer to see the exact thickness of the sections at any moment, but he has also a visible record of the changes from the beginning, and with the ten instruments available it was possible to carry a large number of tests through simultaneously at the identical temperatures, which thus did not need to be kept constant or under uniform illumination. The immersion liquids in the tests below varied from 16° to 20° C.

The plan implied that a series of sections was first hydrated in water to the extent indicated, then the water was replaced by salt solutions, beginning with those in 0.01M concentration. At this concentration no disturbance of the course of slow enlargement was noticeable in the records. At concentrations of 0.03M to 0.04M, however, a slight retardation lasting for an hour or more was noticeable. At concentrations of 0.05M for KCl, NaCl, and $CaCl_2$ a slight but positive contraction ensued. This did not take place in sea-water until a concentration of 0.06M for the contained Na was reached. After contraction for an hour or two expansion was resumed, as shown in figure 1. The consequent increase could not be determined with sufficient exactness to be of value.

The solutions given above, which produce a contraction of the sections, may be taken to be slightly hypertonic to the cells; that they are not isosmotic is obvious; that the contraction of the cells due to increased permeability and loss of water, is brought about by the colloidal action of the various salts seems plain.

The aggregating or combining effect of the salts becomes even more obvious when the effects of the higher concentrations are considered. Sections in concentrations above $CaCl_2$, 0.07M lost the power of expansion, while this did not occur with Na until a concentration of 0.14M was reached, sea-water at 0.16M, and with K until a concentration of 0.18M. It may be safely assumed that these concentrations serve to rend the plasmatic layer from the wall in an irreversible plasmolysis.

This effect is evidently not one of tonicity, as the isosmotic values of critical solutions which produce an irreversible contraction are widely apart. The concentrations, however, do form a series expressing the relative penetrability or permeability of the kations concerned. The aggregating effect which would produce a permanent lessening of permeability is designated by the concentrations given, and the three bases form the series Ca, Na, and K.

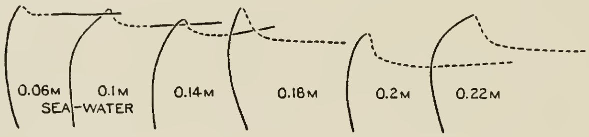


Fig. 1.—Facsimile of auxographic records of living sections of *Opuntia* which were first hydrated in water at 16° to 19° C. for 6 to 9 hours, then placed in solutions of sea-water. When the concentration reaches 0.06M a slight contraction followed by expansion takes place. At concentrations above 0.16M plasmolysis ensues and the contraction is permanent. The portion of the record in which contraction is in progress is reproduced by a dotted line.

Relative Effects of Some Common Ions on Hydration, Absorption, and Permeability, by D. T. MacDougal.

That the action of the common salts of the soil on plants is in the main determined by the ionic mobility of the particles, with modifications due to the varying composition of the living material and with interferences, is suggested by the following data taken from recently published papers and from manuscripts now in preparation:

Total swelling of dried sections of *Opuntia.*

Auxographic measurements, in percentages of original thickness:
KCl, 310. . . .Sea-water, 310; NaCl, 280; $CaCl_2$, 275 at 0.01M; water 255:
Time necessary for satisfaction of living sections of *Opuntia* in salt solutions at 0.01M.:
KCl, 30. . . .NaCl, 28; $CaCl_2$, 36 hours.

Total swelling of living sections of *Opuntia* in salt solutions at 0.01 M.

Auxographic measurements, in percentages of original thickness:
NaCl, 140....KCl, 145; $CaCl_2$, 160; water, 160.

Relative amounts of water absorbed from 0.01M salt solutions by agar-pectin-lecithin cells, contents 20 p. ct. sugar solution, measured by endosmose and displacement:
Sea water $<$ NaCl $<$ water $<$ KCl $<$ $CaCl_2$. at 0.01M.

Relative amounts of water absorbed from 0.01M salt solutions by agar-pectin-gelatine cells, contents 20 p. ct. sugar solution:
NaCl $<$ water $<$ KCl $<$ $CaCl_2$. at 0.01M.

Relative amounts of water absorbed from 0.01M salt solutions by agar-pectin-lecithin-gelatine cells, contents 20 p. ct. sugar solution:
KCl $<$ sea-water $<$ NaCl $<$ water $<$ $CaCl_2$. at 0.01M.

Relative absorption of ions from immersion liquids at 0.01M by agar-pectin-gelatine-lecithin cells, contents 20 p. ct. sugar solution:
Conductivity tests.
NaCl $<$ KCl $<$ sea-water $<$ $CaCl_2$. at 0.01M.

Relative penetration of ions into contents of agar-pectin-lecithin-gelatine cells, contents 20 p. ct. sugar solution:
Conductivity tests.
KCl $<$ $CaCl_2$ $<$ NaCl $<$ sea-water.
Ionic mobilities.
K 64.6....Ca 51, Na 43.6.

PHOTOSYNTHESIS AND METABOLISM.

An Improved Electrometric Method of determining Carbon Dioxide for Photosynthesis Investigations, by H. A. Spoehr and J. M. McGee.

On account of the fact that in determining photosynthetic rates it is essential that consideration be also given to the rates of respiration, it has been found that a method based upon the differential determination of the concentration of CO_2 in the medium surrounding the plant affords the easiest, as well as the most accurate, method of determining the rate of carbon-dioxide fixation by the plant.

The general principle of the electrometric determination of CO_2, as used in investigations on respiration and photosynthesis, has been described in previous reports; it has since been amplified and improved to yield more accurate results, so that 0.002 per cent of CO_2 by volume can be determined with certainty. In employing this method, experience has shown that a number of factors must be given careful consideration. The practice of using single excised leaves, while yielding satisfactory experimental results, demands the determination of exceedingly small quantities of CO_2. It is, moreover, often necessary to increase the CO_2 concentration of the air-stream 5 to 20 times that of normal air, and to reduce the periods of determination of photosynthetic rates to as short a time as possible. The problem then resolves itself into absorbing so completely the relatively large amounts of CO_2 in the air-stream that the very slight differences in the CO_2 exchange of the leaf can be determined with sufficient accuracy.

It is, therefore, essential that the volume of the absorbing solution and the measurements of resistance are commensurate with the accuracy required. Several conductivity cells have been devised for various degrees of accuracy desired. In order to construct a resistance-concentration curve of sufficient accuracy, it was necessary to determine the concentrations of the different solutions of $Ba(OH)_2$ more accurately than could be done by titration with HCl. This was done by allowing definite quantities of the $Ba(OH)_2$ solution to absorb a known quantity of CO_2. On the basis of Benedict's extensive analyses, dry air from open-air sources differs by less than 0.002 per cent. The atmosphere was thus used as a very dilute solution of CO_2 of known concentration, of which carefully measured volumes were drawn through the $BA(OH)_2$ solution and the weight of CO_2 absorbed was calculated.

Thus, e. g., duplicate determinations of CO_2 in 3 and 5 liters of air showed a difference of 0.05 and 0.11 mg. CO_2, respectively. These differences are equivalent to 0.001 per cent by volume of CO_2 in the determinations, an order of accuracy obtained only with the Sondén apparatus. From the data so obtained, knowing the original concentration of the solution, the CO_2 gram equivalent of each 75-c. c. portion was calculated after successive definite volumes of air had been drawn through. Thus a concentration-resistance curve was constructed in which specific resistance was plotted against CO_2 gram equivalents of 75 c. c. $Ba(OH)_2$. The amount of CO_2 absorbed by 75 c. c. $Ba(OH)_2$ could thus be read directly from the curve.

The leaves used in the work on photosynthesis rarely have a rate of CO_2-emission of less than 0.5 mg. CO_2 per hour at 25°. Using a cell with a constant of 85.204, a difference of 1 ohm in the observed resistance of the $Ba(OH)_2$ solution, when calculated as specific resistance, is equal to 0.45 mg. CO_2 on the middle portion of the curve. Hence a milligram of CO_2, when absorbed, would change the observed resistance of the solution 21.7 ohms. The differences in the rates of CO_2 emission or fixation by a single leaf in a half-hour period thus fall well within the accuracy of the method.

Effect of Fluctuations in the CO_2-content of the Atmosphere on the Rate of Respiration of Leaves, by H. A. Spoehr and J. M. McGee.

For practical experimental purposes it is often desirable that the photosynthesis determinations be made in an atmosphere enriched in CO_2. In determining the rate of photosynthesis on the basis of CO_2 fixed, it is necessary also to determine the rate of respiration. It has been very generally assumed that the latter, determined in the dark, remains the same during illumination. A correct estimation of the rate of photosynthesis depends, therefore, largely upon an exact determination of the respiratory value. Moreover, the rate of respiration is very often determined by measuring the CO_2 emitted in a stream of air free of CO_2. It has been found, however, that changes in the partial pressure of the CO_2 surrounding the plant have a profound influence on the rate of CO_2-emission.

When the CO_2-content of the air surrounding a leaf is changed from a lower to a higher concentration, the leaf shows a reduced rate of CO_2-emission for a period following the change, then increases, and finally again attains about the same rate as before the change in CO_2-content was made. Conversely, when the CO_2-content of the air surrounding a leaf is changed from a higher to a lower concentration, the leaf shows a primary increased rate of CO_2-emission and subsequent decrease to the original rate.

The intensity of this increased or decreased rate varies with different species of leaves (*Helianthus annuus, Echinocystis fabacea, Hydrangea hortensis*) as does also the duration of the effect of the change. These results substantiate the opinion that determinations of the rate of photosynthesis in a closed system of air yield spurious results.

The same is true when using aquatic plants where a slightly alkaline solution is produced during photosynthesis. The effect can be avoided either by using a very rapid air-stream, which introduces the difficulty of complete CO_2-absorption, or in the case of aquatic plants by employing a carefully adjusted buffer solution. While the results can in part be explained on the basis of the fact that the rate of CO_2-emission is directly affected by the partial pressure of the CO_2 surrounding the plant, another factor seems to enter, namely, that of the absorption of CO_2 by the leaf material itself.

The Absorption of CO_2 by the Leaf Material, by H. A. Spoehr and J. M. McGee.

The classical investigations of Brown and Escombe established the quantitative relationships governing the diffusion of CO_2 into the leaf. Willstaetter has shown that the killed leaf is capable of absorbing CO_2 in quantities considerably above the amount dissolved in the water of the leaf. An investigation has been begun to determine the nature of the substance which absorbs or adsorbs these relatively large amounts of CO_2. A large variety of plant material, killed and dried by different methods, has been studied. Highest CO_2-absorption was obtained by killing and drying in an oven at 100°. Different species of leaves vary considerably in their absorptive capacity. This is less in leaves which have been illuminated than in those not illuminated. Thorough extraction with cold water removes about 30 per cent of the absorptive material, the concentrated extract also absorbing this quantity of CO_2. Extraction with hot water very greatly reduces the absorptive capacity of the leaf material; the concentrated hot-water extract absorbs very little CO_2. Extraction with hot alcohol reduces the absorptive capacity but slightly. Green leaves and stems absorb considerably more CO_2 than the corresponding etiolated portions. The investigations are being continued on the basis of analytical separation of the mineral, carbohydrate, fatty, and proteinaceous materials of the leaf.

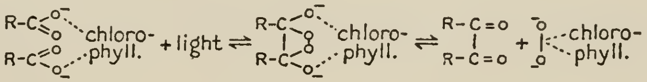
The Reduction of Carbon Dioxide, by Arthur Locke.

Molecular configuration is determined by an equilibrium between attractive (or valence) forces and forces which may be described as instability tensions. Any variation in the instability tension requires a counter variation in the valence forces, which further requires the redistribution of these forces throughout the molecule, residual or intermolecular attractions being sacrificed to preserve stability. When the instability tensions exceed the valence capacity, decomposition ensues until a new equilibrium is reached. The more closely the molecule has already approached its stability limit, the less energy need be added to decompose it. On the basis of the quantum hypothesis this is equivalent to the statement that a lower frequency of radiant energy is required. There is thus a connection between stability and color.

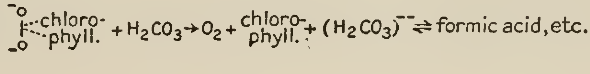
Carbonic acid, being very stable, is restricted to absorption in the ultraviolet. Any activation which renders it sensitive to light of lower frequencies is the result of the production of an increased strain along one of the valence bonds. This involves the imposition of a reducing potential upon an oxygen of the carbonic acid or the substitution of that oxygen by a reducing agent.

There is some evidence that a purely chemical reduction (*b*) of carbonic acid is associated with the photochemical reduction which takes place in plants, in somewhat the following fashion:

(*a*)



(*b*)



Iron may act as a catalyst in this transition. A reconnaisance was made of methods proposed for the reduction of carbonic acid by means of hydrogen peroxide and by means of ferrous iron, hydrogen, or ferrous hydroxide peroxide, which might conceivably act as a result of peroxide decomposition. Repetition of the work of several observers failed to confirm the occurrence of reduction in any *significant* quantity. However, considerable reduction does occur at high pressures and work is being continued upon the possibility of realizing these high pressures in ordinary systems by means of adsorbing surfaces or of micro-bubbles. No positive results have been thus far obtained.

Illuminated solutions of a pigment such as chlorophyll become increasingly metastable, resulting in either coagulation or decomposition. In the presence of an oxidizing agent the reducing tension of the pigment should increase, and vice versa. In the event that the colloidal particles have adsorbed ions from solution, the tension may conceivably be communicated to and released through them as in equation (*a*). Potentiometric measurements demonstrated that the instability tension of different illuminated dye solutions was readily communicated to an electrode of platinized platinum which had been previously polarized. Further experiments with solutions of methylene blue and sugar demonstrated the marked acceleration of the sugar oxidation when the dye is illuminated, as compared with the dark reaction. While the methylene blue is itself reduced, it is regenerated upon the admission of air and may be regarded as a photocatalyst for the oxidation of sugar by air. Experiments in photo-reduction are awaiting an adequate method of disposing of the hydrogen peroxide that may be formed and which reverses the action into photo-oxidation.

Effect of Ultra-violet Light on Carbamino Acids, by H. A. Spoehr and Arthur Locke.

The photochemical reduction of carbonic acid and its salts to formaldehyde has thus far in this laboratory been attended only with negative results. The theory of Siegfried that carbonic acid is not reduced as such in the plant but that CO_2 combines first with amino acids and that these carbamino acids enter the chlorophyll-reduction complex has gained the support of a number of workers in this field. It seemed, therefore, advisable to determine whether solutions of carbamino acids are capable of undergoing photoreduction. Accordingly, the calcium salts of the carbamino acids of glycocoll and alanine were prepared and were subjected to the light of a quartz mercury-vapor lamp under a variety of conditions. It has been reported that illumination of solutions of amino acids in the presence of air results in the formation of oxidation products which might confuse the identification of a reduction product. However, during the periods of illumination used, no trace of formaldehyde, ammonia, or hydrogen peroxide could be obtained from glycocoll or alanine. The addition of $CaCO_3$ or $FeSO_4$ to the illuminated solution was without influence.

The illumination of ice-cold solutions of the calcium salts of glycocoll and alanine carbaminate resulted in the formation of slight traces of ammonia and of formaldehyde, as well as small quantities of methyl alcohol. The results appear to indicate that the conversion of amino acids into calcium carbaminates renders them more sensitive to photo-oxidation, but does not facilitate the reduction of the bound carbonic acid to formaldehyde or its equivalent.

Oxidation of Glucose by Means of Air, by H. A. Spoehr.

The marked stability of hexoses in pure solution toward oxidizing agents as compared to the apparent ease with which these sugars are oxidized in the living organism has led to extensive speculation as to the chemical nature of glycolysis. While it has been known for some time that oxidation of the sugar can be effected by raising the reduction potential of the sugar solutions through the addition of alkali, there is considerable doubt whether the degree of alkalinity necessary to bring this about exists in the living organism. On the other hand, when the hydroxyl-ion concentration is lower (0.3 molar NA_2HPO_4) air is incapable of oxidizing the sugar. For a continuous oxidation of glucose with air it is clear that certain conditions must be met, viz: (1) activation or dissociation of the glucose molecule; (2) activation of atmospheric oxygen through catalysts or oxygen carriers; (3) proper buffer solutions to prevent the accumulation of the acid products of sugar oxidation. After considerable experimentation, these conditions have been most adequately met by the following system: The sugar is dissolved in a solution of Na_2HPO_4 and NaH_2PO_4. This mixture, it was found, decolorizes a solution of methylene blue, and, on passing air through the solution, the blue color is again formed and CO_2 is liberated. However, the rate of sugar oxidation of this mixture is low. A number of substances accelerate the reaction; thus far the most effective agent in this respect has been found to be iron. A large variety of iron compounds have been tried, including a number of complex colloidal preparations. In all of these, however, the iron precipitates out in time, usually as the insoluble ferric phosphate. This was finally overcome by using the complex salt formed by dissolving $FeSO_4$ in sodium pyrophosphate.

The chemical reactions resulting in the complete oxidation of glucose in this manner are undoubtedly very complex, involving a number of steps. In all probability the following reactions express the more important steps, all of which are catalyzed by iron:

$$C_6H_{12}O_6 + \text{methylene blue} \longrightarrow 6CO_2 + 6H_2O + \text{leuco methylene blue}$$
$$O_2 + \text{leuco methylene blue} \longrightarrow \text{methylene blue} + H_2O_2$$
$$C_6H_{12}O_6 + H_2O_2 \longrightarrow 6CO_2 + 6H_2O$$

Thus, by drawing air through a glucose solution containing the sodium-phosphate mixture, the iron-pyrophosphate complex and methylene blue in 0.001 molar concentration, considerable quantities of the sugar are oxidized with the formation of CO_2. The investigation is being continued with a view of determining whether the rôle of the phosphate mixture is that of an isomerizing agent, converting the glucose into levulose, as the latter sugar is much more easily oxidized than glucose, or whether the function of the phosphate is one of salt formation. The rate of reaction can be further increased by the use of certain promoters and adsorbents—this, however, further complicates the system. It is evident that the kinetics of the reaction in the dark and in a homogenous system must first be established before a rational interpretation of the effect of light thereon can be attempted.

Isolation of Phosphatides from Opuntia discata, by Earl B. Working.

The attempt was made in this work to obtain phosphatides from active growing cells rather than resting or storage tissue. The season was unsatisfactory from this viewpoint, as the excessive drought inhibited the growth of new joints of opuntias. It was therefore necessary to use joints of the previous year's growth.

One of the first methods of extraction attempted was by slicing the joints and drying first in the air and then *in vacuo* over H_2SO_4, grinding, and extraction in a large Soxhlet, first with ether and then with alcohol under reduced pressure. The ether extract contained chlorophyll and probably some true fats along with the phosphatides and their decomposition products, and the alcohol extract contained some chlorophyll and rather large amounts of carbohydrate. However, the small quantities that could be handled did not permit satisfactory purification of the phosphatides.

The fresh material was also sliced and extracted immediately with distilled water according to the method of Cranner.[1] By this method a large number of phosphatide fractions were obtained, which all gave glycerine, fatty acids, chlorine, and phosphoric acid as the hydrolysis products. Carbohydrate was very evident in some, and was probably present in all. Some of the fractions were obtained in sufficient quantity to allow proof of both saturated and unsaturated fatty acids, but in no case was a product obtained which seemed pure enough to warrant a quantitative analysis. In one attempt, complete precipitation of the phosphatide from the original aqueous solution was obtained, but attempted repetition was not successful. If this method could be perfected, the aqueous extraction might be practicable; otherwise the yield of phosphatide is seriously limited by the large amount of water to be removed.

The method devised by MacLean [2] for the extraction of lecithin proved fairly successful if very large quantities of material were available. In some of the earlier attempts with this method, a lecithin-like substance was obtained which contained 1.26 per cent N and 2.77 per cent P. Considerable carbohydrate was present. In the latest attempt (in which the product was dissolved in ether and reprecipitated by acetone five times, then emulsified in water and precipitated by acetone five times) the resultant product gave 1.54 per cent N and 3.31 per cent P. Some carbohydrate was still present. Whether this is actually chemically combined (perhaps loosely), or merely physically entangled, is a matter of conjecture. The need of further work is very apparent.

ECOLOGY AND PHYTOGEOGRAPHY.

Experimental Investigations on Roots, by W. A. Cannon.

The physiology of roots has been subject to investigation in this Department for several years, during which time the general problems connected with activities of roots have been outlined, special methods of attack have been developed, and especially designed apparatus has been used, with the investigations carried on *pari passu*. The lack of organized and systematic work on the physiology of roots, despite the evident importance of the subject, enhances the value of such researches.

The ultimate aim of the investigations is to acquire data which will define as clearly as may be practicable the rôle played by the root in the activities of the plant as a whole. Logically, therefore, the scheme implies studies at first on roots *per se,* to be followed by investigations of root-shoot relations. Thus step by step, as the progress of the work indicates, different phases of the topic are brought into focus and subjected to scrutiny. The present report deals mainly with introductory studies on the relation of roots growing in a deficiency of oxygen in the atmosphere of the soil to the soil temperature.

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[1] B. Hansteen-Cranner, Zur Biochemie und Physiologie der Grenzschichten lebender Pflanzenzellen. Meld. f. Norges Landbrukshoiskole 1.1–160. 1922.

[2] Hugh MacLean, Lecithin and allied substances. Monograph on Biochemistry (1918).

Experimental Methods.

The methods employed in the investigations on various activities of roots are in conformity to the present trend of experimentation on the relations of plants to their physical environment, in that, so far as possible, such environmental factors are brought under control and the influence of each studied and evaluated.

The investigations are at present confined wholly to roots and no attempt is made to control the subaerial environment. The methods employed have the following especially important features: The plants experimented with are grown in sand and in glass tubes of a size sufficient to permit a fair amount of root extension and growth in length. The culture tubes are provided with inlet and outlet lateral tubes for the ingress and egress of the experimental gases used. They are kept in thermostats at an angle sufficient to induce the tip of the roots to follow the inner concave surface and thus to be in view. The thermostats as employed are accurate to about 1° C. and are maintained at temperatures between 18° and 30° C. Commercial nitrogen, carbon dioxide, and oxygen are used. The gases are stored at pressure in cylinders from which they are passed into gasometers, where they are mixed as desired, and from which the gaseous mixture is passed under slight pressure to the culture tubes. Volumetric determinations are made of the amount of oxygen present in each culture before and after each experiment or at any other desirable time. These are accurate to about one-fifth volume per cent.

It can be pointed out that the method as employed is apparently appropriate for use in connection with root studies, aside and in addition to those directly concerned with soil temperature and the oxygen supply, including, among others, investigation on root respiration in which quantitative determinations of the carbon-dioxid-oxygen ratio are made, studies on the immediate effect on root-growth of soil solutions different in H-ion contents, as well as work on root-growth in sterilized and unsterilized soils, special phases of the activities of roots, and others.

A detailed account of the methods used and of the apparatus employed is in course of preparation.

Oxygen Deficiency in the Atmosphere of the Soil as a limiting Factor in the Rate of Growth of Roots.

Temperature is known to directly affect the rate of respiration. Thus at medium temperatures, 10° to 15° C., the respiratory ratio is least. The value of the ratio increases at lower temperatures and also at higher temperatures up to about 40°, above which it remains constant until death of the plant takes place. The value of the respiratory ratio is apparently unaffected by the partial pressure of oxygen, at least in aerobes when the deficiency of oxygen is not extreme. It varies with acidity among other factors, and hence plants of unlike habit of growth may exhibit different values of the respiratory ratio.

Although an increase in temperature is usually accompanied by more active respiration, the consumption of oxygen, as referred to above, may not keep pace with the evolution of carbon dioxide, even if the actual amount of oxygen absorbed is greater at higher than at lower temperatures. When, therefore, as will be shown in this report, the amount of oxygen present in the atmosphere of the soil is much below normal, the rate of growth, which is usually related to respiration, is of necessity less than normal. Under such conditions there is a very close relation between the rate of root-growth and the amount of oxygen available to the roots, and the oxygen deficiency becomes a factor limiting growth-rate.

As shown in another paragraph, under conditions of a constant supply of oxygen, especially if the partial pressure is low, the relative growth-rate varies with the temperature in a very definite way. When, however, the temperature of the soil is maintained constant, a variation in the rate of growth of roots can be induced by varying the amount of available oxygen, provided always it is small. This can be shown to be the case by citing a few typical observations.

Potentilla anserina was studied in this regard at 18° and 30° C. and in 1.2 and 2 per cent oxygen. At 18° soil temperature and in normal soil atmosphere a total root-growth in 24 hours of 3.5 mm. was recorded. During the following 24 hours, however, when 1.2 per cent oxygen was given, the growth was 1 mm. only. At the same temperature but in 2 per cent oxygen, the growth during 24 hours was found to equal that under normal conditions of aeration. With the temperature of the soil 30° it was found that, under normal conditions of soil aeration, the growth of the root in 24 hours was 7.5 mm., but in 1.2 per cent oxygen growth ceased. In a soil atmosphere containing 2 per cent oxygen, on the other hand, and at the same soil temperature, the growth during a 24-hour period was 3 mm., or nearly half that to be expected under normal conditions of soil aeration.

Root-growth of *Opuntia versicolor* was studied at 20° and at 30° C., and in 0.5, 1.2, 1.6, and 2.2 per cent oxygen. At a soil temperature of 30° and in normal soil atmosphere a growth of 9 mm. during 24 hours occurred, but in 2.5 per cent oxygen and at the same temperature the growth was reduced to 3 mm. Upon being given 1.2 per cent oxygen for the same length of time and at the same temperature of the soil, however, growth ceased. At a soil temperature of 20° root-growth continued at a slow rate in 1.2 and in 1.6 per cent oxygen, and somewhat more rapidly in the soil containing the latter amount. In another experiment, in which the experimental atmosphere employed contained 0.5, 1, and 2.2 per cent oxygen, the growth for 24 hours had the ratio 1: 2: 4 to 5, or it was approximately proportional to the amount of oxygen present.

Root-growth in *Zea mays* (Golden Bantam corn) was observed in 3.6 and 10 per cent oxygen and at 18° and 30° C. At a soil temperature of 18° and with normal supply of oxygen, the root of the corn increased 12 mm. in length in 24 hours. During a similar period, but in 3.6 per cent oxygen, the growth was 8 mm. and in 10 per cent oxygen it was 10 mm. At a soil temperature of 30° and with normal aeration a growth of 45 mm. was observed. In 3.6 per cent oxygen the growth fell to 19 mm., but in 10 per cent oxygen it became 37.5 mm.

Analogous results were obtained with *Prosopis velutina*, and with the Brazilian sour orange and rough lemon, all of which suggest the possible general applicability of the principle. More intensive quantitative studies on the respiration of the roots of representative species are required, however, to give it exact expression.

GROWTH OF ROOTS AT DIFFERENT TEMPERATURES OF THE SOIL AND IN A CONSTANT BUT DEFICIENT SUPPLY OF OXYGEN.

Within the range of soil temperature favorable for the growth of roots are well-marked cardinal temperatures for growth, by which is meant the lowest temperature at which root-growth of a species begins (the minimum temperature for root-growth), the temperature at which in given time the growth is most rapid (the optimum temperature for root-growth), and the highest temperature at which growth continues (the maximum temperature for root-growth). In any event an appropriate substratum, suitable supply of food material in solution and of water, and adequate aeration are postulated. An absence or great alteration of one essential factor of the soil environment causes especial adjustments and reactions which may materially alter reactions of the root, as shown by disturbance in the rate of growth. Such appears to be strikingly the case when roots are grown in small amounts of oxygen. The results of preliminary experiments appear to indicate, for example, that not only may the rate of growth be greatly modified by the partial pressure of oxygen, as outlined in the preceding paragraphs, but that the cardinal temperatures for root-growth may possibly also be somewhat (perhaps occasionally greatly) changed by the same cause.

In *Prosopis velutina* the optimum temperature for root-growth is about 32.5° and the maximum temperature about 42° C.[1] Under such conditions the aeration of the soil is normal. When, however, the supply of oxygen is much depleted there is apparently a marked alteration of these cardinal temperatures, which is associated with the degree of the oxygen deficiency. Thus, 30° is probably the maximum for root-growth in a soil atmosphere containing 0.5 per cent oxygen, but a fair rate of growth (possibly the most rapid for this oxygen partial pressure) occurs at 20° C.

The optimum soil temperature for root-growth in *Potentilla anserina* is 27° to 30° C. in normal soil atmosphere. When the amount of oxygen is reduced to 1.2 per cent, 27°, or possibly less, is the maximum, while a fair growth-rate, possibly the most rapid in this amount of oxygen, goes on at 18° C. The optimum temperature for growth of roots of *Potentilla* in 2 per cent oxygen appears to be about 20° C., above which the rate rapidly falls.

In *Zea mays* the optimum temperature for growth of the shoot is 33.7° and the maximum temperature is 46.5° C. The cardinal growth temperatures of the root of the species used, Golden Bantam corn, have not been determined. It is apparent, however, that in a soil atmosphere deficient in oxygen, although containing a relatively good supply, the maximum and optimum temperatures for growth are both much lower than when the supply of oxygen is normal.

The optimum temperature for root-growth in *Opuntia versicolor*, with normal aeration conditions, is about 32° C. When 2.5 per cent oxygen is given the roots, the growth-rate becomes less at all temperatures, but the optimum appears to be about as under normal oxygen relations. In a soil atmosphere containing 1 per cent oxygen, however, 32° is the maximum or above the maximum for root-growth, while active growth occurs about 10° below this, which may be the optimum for the oxygen partial pressure. In 1.5 per cent oxygen the actual rate of growth of the roots is not far different at 20° than at 30°, although the relative growth-rate at the latter temperature is much less than at the former soil temperature.

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[1] W. A. Cannon, Relation of the rate of root-growth in seedlings of *Prosopis velutina* to the temperature of the soil. Plant World, vol. 20, p. 320, 1917.

The observations as above outlined on the relation between oxygen partial pressure and the maximum and optimum temperatures for root-growth appear to indicate that where the oxygen deficiency is critical these cardinal temperatures are greatly lowered, but where the amount of available oxygen is above this the optimum temperature at least is not greatly affected.

THE GROWTH RATIO, OR INDEX OF GROWTH, $\frac{r}{R}$; THE RELATIVE GROWTH OF ROOTS IN A DEFICIENCY OF OXYGEN.

In studying the reaction of roots to a small amount of oxygen in the soil it has been found advisable, owing to individual variation, to use each specimen experimented with as its own control by first observing the rate of growth, at known and constant soil temperature and for a given period of time, and immediately afterward by measuring the growth for the same time and temperature but while in any desired gaseous mixture. The root-growth in the experimental atmosphere divided by the growth under conditions of normal aeration, $\frac{r}{R}$, is the growth ratio, or growth index, for the temperature and oxygen supply used. It is the relative root-growth, expressing not the actual amount of growth, but merely the capacity of the root for growth under the temperature and aeration conditions of the experiment.

The growth ratio, being usually less than unity, reveals the depressing effect on growth of a deficiency of oxygen. This varies greatly in different species, different temperatures, as well as different percentages of oxygen. In *Allium cepa*, in 1.6 per cent oxygen, ratios of 0.5 to 0.9 were obtained at 17° and 0.12 to 0.25 at 22° C. In 2.8 to 3 per cent oxygen and at 27° the ratio was found to be 0.8 to 1. The roots of *Opuntia versicolor* in 1.6 per cent oxygen had a ratio of 0.6 at 22° and 0.3 at 30°. In the rough lemon, in 2.8 per cent oxygen, a ratio of 1 was obtained at 22°, but at 27° it was only 0.4 to 0.7. The ratio in the Brazilian sour orange at 27° was 1 with 1.2 per cent oxygen and 0.6 with 8 per cent oxygen, while at 22° a ratio of 0.5 was obtained in 0.8 per cent oxygen. At 27° and in 2.8 per cent oxygen the growth ratio in *Prosopis velutina* was 0.7, and at 20° it was 0.14 in 0.6 per cent oxygen, 0.3 in 0.8 per cent oxygen, and 0.7 in 2.2 per cent oxygen. In *Potentilla anserina* and in 2 per cent oxygen the ratio was 1 at 18°, 0.3 at 27°, and 0.2 at 30° C. At a temperature of 26° in *Salix lasiolepis* the ratio was 1 in 1.6 per cent oxygen, but at 30° it was only about 0.2. In 3 per cent oxygen *Zea mays* gave a ratio of 0.28 to 0.39 at 17°, 0.2 at 22°, 0.08 at 27°, and 0.06 at 30° C. The same variety of corn (Golden Bantam) in 3.6 per cent oxygen had a ratio of 0.6 at 17° and 0.4 at 30°, while in 10 per cent oxygen the ratios for these temperatures were 1 and 0.89, respectively.

From the summary given above it will appear that although different species may have unlike growth ratios, yet the ratios have this feature in common, namely, they decrease in value with the mounting temperature of the soil for the temperature range employed. In the face of a constant but deficient supply of oxygen such would be expected, inasmuch as the oxygen requirements are greater at higher than at lower temperatures for other organs than roots and the same should hold with these organs.

Although the data at hand are not sufficient to permit satisfactory comparison of the $\frac{r}{R}$ for the different species studied, yet they suggest the lines on which such comparison might be instituted. For example, it is instructive to examine what species were found to have normal growth, or a ratio of 1, at parallel temperatures, and under what oxygen partial pressure. Thus, at a soil temperature of about 17°, normal growth was found in *Potentilla* 2 per cent oxygen; in *Zea* 10 per cent oxygen. At a temperature of 20° to 22° normal growth took place in *Salix* in 1.6 per cent oxygen and in the rough lemon with 2.8 per cent oxygen; and, finally, at a temperature of 27° the growth was at the normal rate in the Brazilian sour orange in 1.2 per cent oxygen and in *Allium* in 3 per cent oxygen. So far as the species mentioned are concerned, therefore, the results suggest the relatively great tolerance for oxygen deficiency of *Potentilla*, *Salix*, and the orange as contrasted with the tolerance of *Zea*, the lemon, and *Allium*. A comparison of the growth ratios for higher soil temperatures should yield even more striking results.

Diffusion of Oxygen through Leafy Bases of Herbaceous Plants and through Bulbs.

During the course of the experiments on the oxygen relations of roots it has occasionally been observed that there is sometimes an inward diffusion of oxygen not to be accounted for by faulty seals or connections and apparently attributable only to diffusion in some manner through the plant itself. This was seen in *Potentilla*, *Zea*, and *Allium* especially, and was not found in young plants of other species, as *Prosopis*, in which the leaves take their origin wholly above the seals of the cultures. It was concluded, therefore, that the enriching of the soil atmosphere with oxygen was in some manner connected with plants with overlapping leaves or scales.

In the earlier experiments with *Allium*, *Potentilla*, and *Zea*, the base of the plant was sealed within the tube in such manner that it was included with the subterranean portion beneath the seal. Under such conditions there was no outward gas leak, but analyses showed occasionally that the experimental atmosphere contained as much as 1 per cent more oxygen than the gasometer from which it was taken. Blank controls indicated that the inward diffusion was not associated with connections or seals. In the case of *Allium*, when the bulb was coated with vaseline or sealing-wax, the variation in oxygen-content was much less than in the cultures with uncoated bulbs, and when the seal was at the crown of the main root, the bulb remaining outside the culture, there was no inward diffusion. Similar results were obtained in *Potentilla* and *Zea*. In the former, the cut ends of the root-stock were waxed and the seal placed below the origin of the leaves, under which condition inward diffusion of oxygen ceased.

The oxygen may have been derived, in part at least, from the tissues of the plants or from between the closely overlapping leaf bases or scales. Owing, however, to the apparently unequal capacity of these organs to contain the gas, which did not appear to be reflected in the amount of oxygen added to the experimental atmospheres used, such tissues were not considered to be the sole source of the supply. This conclusion was supported by the relatively long period over which the inward diffusion continued. It appears probable, therefore, that inward diffusion of oxygen from the atmospheric air through or between the tissues of the plants referred to and into the soil can occur at a slow rate.

Internal Factors governing the Seasonal Changes in the Transpiration of Encelia farinosa, by Edith B. Shreve.

A publication[1] appearing within the year has shown that *Encelia farinosa*, a desert perennial having a mesophytic form of leaf in the cool, moist months, and a xerophytic form in the arid season, reduces its responses to the maximum evaporative power of the air in June to about one-fifth of the January value. It was shown further that the external factors influencing the changes in transpiration could be expressed thus: $\frac{T}{E \times S}$, where T is the transpiration per unit area for 24 hours, E the evaporation from an atmometer for the same period, and S the soil-water content based on dry weight.

A series of experiments has now been completed that was undertaken with the hope of discovering the internal factors that govern this reduction in transpiring power. Work was conducted on isolated disks from leaves taken at the different seasons, in order to eliminate the immediate influence of variations in the water-content of soil and plant parts. The conclusions from these experiments are as follows:

1. The difference in anatomical structure of the mesophytic and xerophytic leaves does not account for the greater resistance to water-loss during the arid season.
2. When disks of equal areas are cut from the two types of leaves immediately before sunrise and placed under identical external conditions, the water-loss (E_d) from them is found to vary inversely with their total imbibitional capacity (M) and directly with the original water-content (O), so that the expression $E_d \times \frac{M}{O}$ gives a value that approaches a constant so nearly as to be remarkable for this type of work.
3. The total imbibitional capacity of both types of leaves varies with the original water-content and with the dry weight.
4. The less the original water-content the greater the amount of soluble material that diffuses into the water which surrounds imbibing disks. The evidence makes it probable that in the attached leaf the differences in water-content are accompanied by similar changes in the amount of soluble material that passes out of the leaf by diffusion to other parts of the plant.
5. The combined action of the external and internal factors is such that the ratio of evaporation to soil moisture affects the water-content of leaf-tissue; this affects the imbibitional capacity, and it in turn affects the resistance to water-loss exhibited by the leaf tissue.

Ecology of the Santa Lucia Mountains, by Forrest Shreve.

In continuation of work on the vegetation of the Santa Lucia Mountains, instrumentation was carried on in the summer of 1923 at a locality 15 miles south of the Coastal Laboratory and adjacent to the sea. In this part of the Santa Lucias the cañons are occupied by a highly mesophytic forest of redwood and tan oak, and the ridges, running at approximately right angles to the coast-line, are clothed with low chaparral of a composition depending on the soil and underlying rock. The ridge lying between Palo Colorado Cañon and Rocky Creek is formed mainly of sandstone, its soil is a fine sand very poor in organic matter, and its summit is covered with an open chaparral of manzanita. The vegetation of this ridge is the most xerophytic that has been observed in any habitat on the seaward slope of the Santa Lucias. Instrumentation has been devoted to securing a comparison between the conditions of evaporation and soil moisture on Palo Colorado Ridge and in the heavy stand of redwood in Rocky Creek, three-quarters of a mile distant and 500 feet below. During the course of the rainless summer the soil moisture on the ridge, at a depth of 6 inches, has fallen from 4.1 per cent to 3.7 per cent, and in the flood-plain of the creek from 18.2 per cent to 13.0 per cent. The evaporation on the ridge has varied from 15.6 to 22.9 c. c. per day, and in the floor of the cañon from 5.6 to 7.0 c. c. per day.

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[1] Shreve, E. B., Seasonal changes in the water relations of desert plants. Ecology, IV, 3 (1923).

The ratio of evaporation to soil moisture is a datum of importance in indicating the conditions of a habitat with reference to the water relations of plants, and its value has been determined for several localities in previous work. For Palo Colorado Ridge the value of the ratio is 5.2 and for Rocky Creek is 0.4. The previously determined value of this ratio for Carmel is 3.5, and values for four other localities in the Santa Lucias, at different altitudes and farther from the sea, are all greater than the value for Palo Colorado Ridge—that for the summit of Chew's Ridge, at 5,000 feet elevation and 20 miles from the sea, being 14.1 (see Annual Report, Year Book, No. 19, 1920, p. 78). Since the ratio of evaporation to soil moisture is an index of the aridity of a habitat, it is of interest to note that the value for the most xerophytic habitat in close proximity to the sea is little more than one-third as great as that for Chew's Ridge, where the summit is dominated by a similar type of chaparral and the adjacent slopes by an open stand of Coulter pine. For comparison it may be noted that the ratio at Tucson in the dry early summer is 50.5, but falls to 3.3 on the adjacent mountains at 8,000-feet elevation. The ratio for Rocky Creek is the lowest that has been determined for any of the habitats investigated, and its value, 0.4, may be taken as typical of the highly mesophytic conditions which favor the growth of the redwood. Comparison with the ratio for Tucson indicates that the soil and atmospheric conditions make the maintenance of a balance between water income and water outgo 126 times as difficult in the habitat of the giant cactus as in that of the redwood.

Conditions influencing Soil Temperatures, by Forrest Shreve.

Our knowledge of the temperature of the soil is very far behind our knowledge of atmospheric temperature. Being outside the realm of climatology, it has remained as one of the least investigated and most poorly known of the physical conditions of biological importance. Work on certain aspects of soil temperature has been continued during the past year with reference to the influence exerted upon it by accompanying conditions. So large is the number of these conditions that it is only by their separate investigation that we shall be able to understand the rôle of each of them in determining soil temperature and to evaluate their importance with reference to plants and animals.

The influence of the color of the soil surface was investigated at Tucson in the spring of 1923. Three soil thermographs were installed, 4 feet from each other, at a depth of 3 inches in a brown clay of basaltic origin. A preliminary run of two weeks showed a correspondence of the maxima of the three instruments with 1° and of the minima within 2°. An area 4 feet square above one of the bulbs was then blackened by application of drop black dissolved in turpentine, this giving a uniform matt black to the soil and small rock particles. Over the second bulb the soil was covered with a very thin layer of crushed mortar, so as to secure a uniform white without any minute reflecting surfaces. The soil over the third bulb was left in its natural light-brown color. The four succeeding weeks were clear, with the exception of two partly cloudy days, and there was no disturbance of the artificial surfaces in this time. During the first four weeks the average maximum of the black soil was 2.8° above that of the control, and the average maximum of the white soil was 7.7° below that of the control, meaning a difference of 10.5° between the black and white soils. The average minima, as would be expected, were nearly identical. While these results are what would be expected from physical theory, they are of interest as showing that the superficial layers of natural desert soils under constant insolation are only about 3° cooler than under the conditions of surface color that give the maximum absorption of heat rays. The difference between the superficial temperature of natural soils that are nearly white and those that are very dark would never be greater, at this latitude, than the difference of 10.5° found in this experiment.

At the Coastal Laboratory, in the summer of 1923, an investigation was begun on the influence of soil moisture as affecting the temperature of the soil. Three soil thermographs were installed in adjacent plots with the bulbs at a depth of 6 inches. The soil was a fine sand with considerable organic matter near the surface and a compact structure below, with a small admixture of clay. The surface was kept bare. After a preliminary run to assure identity of readings, one of the plots was given one weekly sprinkling equivalent to 0.5 inch of rain, the second plot the equivalent of 0.25 inch of rain, and the third left as a control. Soil-moisture samples were taken weekly at 6 inches, just before each wetting. The results show that the cooling due to the increased soil moisture was within 1° to 2° of the same for the two amounts of simulated rainfall. The lowering of 5° to 6° below the control lasted for only 48 hours after wetting, affecting maxima and minima alike. Thereafter for three days the moistened soils were only 2° to 4° below the dry soil. On the last two days of each week the temperatures in the three plots were the same, and the moisture of the irrigated plots had fallen to that of the control. The small effect of increased moisture and its brief duration are probably typical of all soils of light texture, from which evaporation is active and in which percolation is great. It is planned to extend the work to other types of soil, both at Carmel and Tucson.

Strand Vegetation of the Pacific Coast, by William S. Cooper.

Two weeks during the summer of 1923 were spent in completing field work upon the strand vegetation of the Monterey region. The usual annual counts and measurements of permanent plots, established in 1919, were made. Forty-five photographic records of 1-meter areas were obtained. The rainfall for the preceding wet season was measured at nine stations within a radius of 20 miles from Carmel, the results confirming conclusions drawn from previous studies. With the aid of Mr. Rémond Richardson, of the Department of Geology of Leland Stanford Jr. University, a physiographic survey of the dune region of Monterey Bay was made, the recent history of the coast being worked out and the limits of the dune area determined as accurately as possible.

Bacteria in Arid Soils, by Laetitia M. Snow.

The work has been undertaken in order to compare the types of bacteria in arid soils exposed to different climatic conditions.

The plan is to use soils as nearly as possible similar in physical characteristics, but situated in different parts of the country, such as wind-blown sand from the Atlantic and Pacific coasts, around the Great Lakes, and in the center of the continent.

A collection of soil samples was made at each of two points in Brewster County, Texas, but as the soils in both regions had a large proportion of clay, the results may not be comparable with those from sandy soil in other regions.

At Tucson samples were collected from the south bank of Pantano Wash. This soil was of a loose, sandy nature, giving clear evidence of wind action, and had probably not been under water, other than rain, for a sufficient length of time for the micro-flora to become established.

Samples were taken at depths of 6 inches, 1 foot, and 2 feet, from three different points, placed in Mason jars, and returned to the laboratory. The soil from each depth was thoroughly mixed and plated in various dilutions in nutrose agar. From these plates total counts, and counts of casein digesters and nondigesters, were made at the end of 6 and 10 days, and after the last count all colonies showing the slightest difference to the naked eye were fished and streaked on nutrose agar.

The data are very incomplete and definite results can not be given at this time, but the observations seem to indicate that:

1. The greatest number of aerobic forms, capable of growing on the medium used, occurred at a depth of 1 foot, the smallest number at 6 inches, while that at 2 feet was intermediate.
2. At 6 inches and 1 foot the casein digesters were more numerous than the nondigesters, while at 2 feet the reverse is the case.
3. As far as could be distinguished from the colonies at the time of fishing them, the actinomycetes predominated and increased with the depth, the molds were scarce, while of the colonies apparently bacteria or yeasts the white forms far outnumber all others, followed at some distance by yellow. A few colonies each of red, pink, orange, and brown forms occurred.
4. Eighty-one transfers were made and stored for future study.

Composition of the Water of the Salton Sea, by Earl B. Working.

The sample for the 1923 analysis of the water of the Salton Sea was collected June 18. Results were as follows, in parts per 100,000:

Total solids (at 110°)	3,893.81
Ignited at dull red heat	3,765.44
Organic matter and water of hydration	128.37
Sodium, Na	1,239.7
Potassium, K	13.665
Calcium, Ca	68.371
Magnesium, Mg	65.933
Aluminium, Al	0.625
Iron, Fe	0.0363
Chlorine, Cl	1,832.0
Sulphate radicle, SO_4	537.85
Carbonate radicle (total CO_3)	16.86
Fixed CO_3 (not removed by boiling 60 minutes)	12.87
Silicate radicle, SiO_4	2.69
Phosphate radicle, PO_4	0.067
Nitrate radicle, NO_3	0.173
Borate	Present
Lithium	Present
Copper	Trace

The previous analyses from 1907 to 1911, inclusive, gave the carbonate after partial or total evaporation, which should compare approximately with the figure given above as "Fixed CO_3." Analyses in 1912 and following years reported total CO_2, which, in this sample, amounted to 12.365.

There has been considerable discussion of the disappearance of the phosphate ion from the Salton water; so this determination was made with special care; 6 liters of water were evaporated down and most of the NaCl and $CaSO_4$ removed by crystallization, with careful washing to avoid losing any phosphate. While the results show a loss as compared with the figures of 1910 and preceding years, it does not seem to be so great as indicated by some of the analyses of intervening years. The figure obtained for nitrates is undoubtedly too low. Evaporation was carried out at atmospheric pressure, and some nitrate was surely decomposed with the oxidation of a portion of the organic matter present. Borate and lithium were determined only qualitatively.

General observations indicate that there has been very little decrease of the volume of the water of the Salton Sea since 1919, the date of the last analysis.

DEPARTMENT OF EMBRYOLOGY.[1]

George L. Streeter, Director.

In preparing this account of the activities of the Department of Embryology during the past year, I have grouped the individual investigations under the following headings: (1) Studies on the structure and function of the cell; (2) Studies on the structure and development of individual organs; (3) Anthropological studies on the growth of the fetus; (4) Studies bearing on the physiology of reproduction; (5) Studies on the pathology of the fetus. This classification is, of course, only one of convenience, and it is to be borne in mind that the various studies are closely interwoven and have many contacts with each other. The purpose of all of them, however, is to provide a better understanding of the factors that finally determine the structure of the human body.

STUDIES ON THE STRUCTURE AND FUNCTION OF THE CELL.

Heart-Muscle Cells.

In my last report I described how Professor W. H. Lewis, by using cultures of liver-tissue, succeeded in isolating living endothelial cells and thus was able to determine the morphological characteristics of that cell type. During the past year he has accomplished the same for heart-muscle. He found that by cultivating chick-embryo tissue in a Locke bouillon-dextrose medium, the heart-muscle cells in about 8 per cent of the cultures migrated out along the cover-glass, where their structure and behavior could be clearly observed. As these cells migrate out they form either an adherent reticulum or an adherent membrane, in which the distinct outlines of the cells can be recognized. Dr. Lewis finds here no evidence of a true syncytium, which is in confirmation of his observations on other tissues. Individual cells in these outgrowths can be seen pulsating, and at rates different from the cells of the explant, the other cells of the reticulum or membrane, and even from the adherent neighboring cells, which proves their physiological as well as morphological independence. In accord with the previous observations of Mrs. Lewis, he finds that myofibrils can not be seen in the living cells, but are brought out by fixation. They are thus artifacts in the sense that their appearance is dependent upon the manner in which the contractile substance of the cell is coagulated. The fibrils vary in length and thickness down to the limits of visibility; they may be smooth or cross-striated and in some cells they may be entirely absent, yet all these different cells may have been beating rhythmically before fixation. The myofibrils are never found extending from one cell to another. As another characteristic, Dr. Lewis found that when these cultures were tested for glycogen it was present only in the muscle-cells.

Transformation of Mesenchyme into Mesothelium.

While studying cultures of heart-muscle cells, Dr. Lewis noted that the multipolar mesenchyme cells which migrate out beneath the cover-glass as a loose adherent reticulum could be observed to change, under the eye, into a flat mesothelial membrane. This striking transformation is accomplished by a partial withdrawal of the long processes and a coincident spreading out of the cytoplasm of each cell until it abuts the cytoplasm of its neighbors in straight or curved lines. The sharp intercellular boundaries can be seen in the living cultures as well as after iodine fixation or silver-nitrate treatment. There may, however, be some overlapping of the cell edges. At the periphery of the membrane transitional cells, varying from mesenchyme to mesothelium, are found. As the cultures become older the mesothelial membranes may loosen up into reticular cells, which finally contract into more or less globular forms. The mesothelial cells on fixation often exhibit distinctly marked fibrils extending to the periphery of the cell. These appear to be coagulation fibrils, similar to those in fixed endothelial cells. The observation of this transformation of mesenchyme into mesothelium provides the embryologist with an explanation for many developmental phenomena not heretofore clearly understood.

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[1] Address; Johns Hopkins Medical School, Baltimore, Maryland.

VIABILITY OF CELLS.

Dr. W. H. Lewis and Dr. C. C. McCoy, using new criteria of death, have determined the period of survival of the different types of cells and under various conditions after the death of the animal. Experience with tissue-culture has shown that all types of living cells either have or can develop granules and vacuoles which possess a marked affinity for neutral red. In the ordinary strengths this dye does not stain the cytoplasm or nucleus, nor does it seem to injure the cell. In dead cells, however, the granules and vacuoles do not take up the neutral red as they do in living cells, but the dye, if it be strong enough, stains the whole cell diffusely. Granules and vacuoles that have been colored with neutral red lose their color when the cell dies and the whole cell becomes more or less diffusely pink. In addition to this specific reaction to neutral red, there are definite changes in the texture of the cytoplasm and nucleus that are discernible in dead cells, and the nuclear membrane becomes more marked. Tissue-cultures have shown that most cells not only survive, but move about and multiply for many days after removal from the body, and it is well known that epithelial cells have been cultivated for months, and connective-tissue cells may live and multiply for years if given the proper environment. Under ordinary circumstances, however, at the death of the animal all the cells of the body are subject to great functional disturbances. With the cessation of heart action all the tissues are immediately deprived of their chief source of oxygen, their food-supply, and the pathway for the elimination of their waste products. Since the various types of cells differ from each other in their chemical and physical constitution, in the rate of metabolism, in the amount of oxygen, various salts and foodstuffs used, and in the chemical composition of their waste products, it is clear that they will react differently when the animal dies and their environment changes. The period of survival depends on how well each type of cell is naturally fitted to live under the abnormal conditions. In order to test these factors and thus obtain further knowledge of the make-up of different cells, Dr. Lewis and Dr. McCoy carried out experiments the results of which are shown in the accompanying table. Regarding the interesting problem as to the nature of granules and vacuoles, their observations tend to show that these are waste products of autolytic or self-digestive processes, and that their affinity for neutral red is a coincidence.

The following table shows how long various cells of the body survive, under different conditions, after death of the animal (rat). The cells were regarded as alive so long as they reacted specifically to neutral red and so long as the nucleus remained homogeneous, without trace of a nuclear membrane. Series I shows a small fragment of tissue aseptically removed and kept in a moist chamber on ice; II, small fragments of tissue kept at room temperature in neutral-red solution; III, entire animal kept on ice; IV, entire animal kept at room temperature.

	Series.					Series.			
	I.	II.	III.	IV.		I.	II.	III.	IV.
	hrs.	*hrs.*	*hrs.*	*hrs.*		*hrs.*	*hrs.*	*hrs.*	*hrs.*
Large macrophages	240	144	120	24	Brain macrophages	96	48	96	2
Tracheal cartilage	240	144	120	24	Pancreatic epithelium	96	49	96	3
Kidney epithelium	240	120	120	6	Red blood-corpuscles	72	24	24	1
Smooth muscle	240	120	12	3	Liver cells	96	15	12	.....
Salivary gland epithelium	192	120	96	3	Sertoli cells	96	12	.....	3
Bladder	192	120	72	3	Mesenchyme	72	72	48	3
Tracheal epithelium	192	120	120	6	Ovarian follicular cells	72	30	48	1
Tongue epithelium	192	48	96	.....	Uterine epithelium	72	53	12	1
Endothelium	168	72	12	3	Uterine gland cells	72	24	12	1
Small lymphocytes	168	48	60	6	Epididymis epithelium	48	18	.....	3
Large lymphocytes	168	48	60	6	Adrenal cells	24	32	.....	3
Microcytes	168	48	.....	3	Fat	0	18	.....	1
Lung epithelium	144	52	48	3	Intestinal epithelium	0	18	.....	.....
Leucocytes	120	24	36	11	Nerve cells	0	1	.....	0
Kupffer cells	120	49	60	12	Skeletal muscle	0	0	.....	0
					Heart muscle	0	0	.....	0

INGESTION AND DESTRUCTION OF BACTERIA BY CONNECTIVE-TISSUE CELLS.

In previous reports I have referred to investigations of Mrs. M. R. Lewis and her coworkers in this laboratory, tending to show that the protoplasm of living connective-tissue cells possesses an intense digestive power which is capable of breaking down foreign bodies, such as melanin-pigment granules, white of egg, red blood-cells, avian tubercle bacilli, *Bacillus tumefaciens*, and various other organisms. During the past year Mrs. Lewis has experimented with an organism (*Bacillus radicicola*) that ordinarily lives and multiplies in living protoplasm inside of certain cells of the legumes. She found that these organisms, although able to survive within the plant cell, were promptly ingested and destroyed by the connective-tissue cells when inoculated into tissue-cultures from chick embryos. Those not ingested, but simply lying against a cell, were not destroyed or apparently affected, showing that the strong chemical action of this particular protoplasm is limited by the cell membrane. She further finds that the power of digesting the organism seems to be in the homogeneous cytoplasm and not in the specific granules or vacuoles. While these experiments were prosecuted for the purpose of learning more definitely the nature of the processes of the living cell, they have at the same time a bearing that may be of importance to the pathologist, particularly with reference to phagocytosis. This function has been ascribed by the pathologist almost wholly to leucocytes. From the great number of organisms and other foreign bodies which the connective-tissue cells are able to destroy in tissue-cultures, we may conclude that these cells play a larger part in phagocytosis than has been supposed, and it may be that the rapidity with which the ingested organism is destroyed is the reason why this phenomenon is so rarely observed in the animal body. Owing to the favorable conditions under which the process of phagocytosis can be studied in inoculated cultures of connective-tissue cells, Mrs. Lewis was able to observe each step, a very complete account of which is given in her publication. I shall have occasion to return to the subject of phagocytosis in connection with the work of Dr. Cunningham.

Janus-Green Granules in Visual Cells.

The living visual cells of the embryo and adult fowl have been studied by Mrs. M. R. Lewis in respect to their reaction to janus green, and it was found that, although certain granules reacted to this stain, it did not color those structures which, in fixed material, appear to be mitochondria. In newly hatched and adult specimens, the janus-green granules are assembled in a mass just proximal to the fat-globule and correspond to the so-called ellipsoid of fixed and stained material. There are also a few scattered granules around the nucleus. In the visual cells of progressively younger embryos they are less and less closely aggregated, until in embryos of 15 days' incubation one finds them mostly as filaments arranged axially throughout the elongated portion of the cell. At this time there are also more granules around the nucleus. In embryos of 11 days' incubation the janus-green granules are largely segregated in the protoplasmic bud. In studying these cells, Mrs. Lewis found that their filamentous outer segment exhibits changes that are strikingly like those seen in the sarcostyles of insect wing-muscle. They contract, become cross-striated and segmented, or are broken up into disks.

Giant Centrospheres in Xanthomatous Tumors.

In his study of the giant centrosphere that is found in degenerating tissue-cultures, Dr. Lewis pointed out that it is identical with the cancer-cell inclusion known by the name of *Plimmer body*, and he suggested that these bodies might be found in pathological conditions other than cancer. This prediction has been fulfilled in part by the discovery of the giant centrosphere in xanthomatous tumors. Dr. D. T. Smith studied 17 specimens of this rare tumor and found that giant centrospheres were present in the pigment-containing cells of 9 of them. Where there was no degeneration they appeared to be absent, and the whole evidence now points to their being related to a disturbance in the metabolism of the cell.

Migratory Cells in Tissue-Cultures of Spleen.

When minute pieces of the spleen from young chick embryos (7 to 9 days) are placed in a suitable culture medium, there ensues a profuse growth of mesenchymal cells and frequently of broad sheets of mesothelium. Some blood-cells also migrate out. In growths from older embryos, mesenchymal and mesothelial cells are seldom seen, whereas blood-cells are present in great numbers and varieties. On account of the particular interest that is now associated with the study of living blood-cells, Mr. David Rioch has taken advantage of the new method of approach offered by these spleen cultures to observe the structure and behavior of blood-cells under these conditions, particularly their locomotion, phagocytosis, and reaction to dyes. His observations upon the phagocytic power of the blood-cells were carried out, for the greater part with melanin granules, by placing teased pieces of the retina in the culture along with the growing spleen. Phagocytosis of the granules was clearly not the result of any purposeful movement on the part of the cell, but the result of chance contact. Furthermore, a certain extent of surface contact was necessary, no melanin granule being taken in unless it adhered to the cell throughout its entire length. The behavior of the foreign substance after entering the cell was essentially the same as that described by Dr. Smith, to which I referred in a previous report.

From the reaction of the cells to vital dyes, Mr. Rioch concludes that granules and vacuoles are not the result of a specific interaction of the dye and the cell, because similar bodies appear in unstained preparations, while in certain of the stained preparations no vacuoles or granules were observed in either the lymphocytes or granulocytes. However, the number of granules is increased in more concentrated solutions of the dye. Amœboid movement of the blood-cells and macrophages can be easily observed under the conditions attending Mr. Rioch's experiments, and he found that each type exhibited its own characteristics. These he describes in detail. It is of interest to add that in smears of the spleen he found very few endothelial cells and obtained no outgrowth of them in the cultures. It would appear that endothelium is not abundant in the spleen, since endothelial cells grow profusely in cultures from tissues in which these cells are present.

PHAGOCYTOSIS.

During the past few years considerable attention has been devoted in this laboratory to the phenomenon of phagocytosis, as readers of our previous reports will remember. Studies on living cells subjected to vital dyes, pigment particles, and carbon particles have made it possible to determine fairly well the physical nature of this phenomenon, and experiments on living animals have shown the important rôle it plays in the absorption processes of the body, both in health and disease. Dr. R. S. Cunningham has taken an active part in these studies, and during the past year has made further advances. He has shown that the chief means of transfer of granular material from the peritoneal cavity into the diaphragmatic lymphatics is phagocytosis, and this is accomplished, not by free phagocytic cells, but by the mesothelial lining of the diaphragm and the lymphatic endothelium. He proved this by injecting particulate matter of various sizes (lampblack, carmine, erythrocytes) into the peritoneal cavities of young cats. The animals were killed at different intervals and the diaphragm and anterior mediastinal glands examined histologically. Phagocytized particles were found in the glands after an exposure of 5 or 10 minutes, and at the end of 30 minutes all of the lampblack and carmine had been phagocytized. Large numbers of granules could be seen both in the diaphragmatic surface cells and in the lymphatic endothelium. An occasional red blood-cell had been taken within the cytoplasm of the endothelium. Careful examination of material exposed 30 minutes or less failed to show the foreign matter being carried through by free phagocytic cells, and there was no evidence that any of the material was passing between the lining cells instead of through the cytoplasm. It is quite probable that later on (after 30 minutes) leucocytes do bring into the capillaries many granules, but it is also probable that the large inflow of free granules through the phagocytic activity of the intervening cytoplasmic walls continues so long as any remain free in the peritoneal cavity.

Since the diaphragm is primarily a respiratory muscle, it would seem possible that the power of absorption of particulate matter from the peritoneal cavity, as actively shown by the lymphatics of the diaphragm, might have a mechanical relation to the act of respiration. In order to test this possibility, Dr. Cunningham has studied absorption in the fetus (cat) before and after respiratory mechanism is developed. His experiments make it evident that absorption through the diaphragmatic lymphatics does not take place to any marked extent in the earlier stages, but increases with age, until at term it is quite appreciable, although even then the absorption is slower than in the newborn and adult. In fetuses under 50 mm. in length, when no respiratory movements can be elicited, no carbon particles reached the anterior mediastinal nodes. In fetuses between 75 mm. and 90 mm. long, when spasmodic efforts at respiratory movements are first observed, a small amount of granular material had reached the anterior mediastinal nodes after an exposure of one hour. Definite respiratory movements are made by fetuses between 90 mm. long and term, and in these a considerable absorption had taken place at the end of an hour. It is thus obvious that the absorption of particulate matter from the peritoneal cavity via the diaphragmatic lymphatics becomes active at a period at which the fetus begins to make respiratory movements, and after birth, with the beginning of active respiration, there is a decided increase in the amount and rapidity of absorption. The rate of absorption and the muscular activity of the diaphragm are unquestionably associated, and one must suppose that the movements of the diaphragm against the adjacent viscera result in a favorable placing of the granules or adding a necesary movement or pressure to induce their ingestion by the cytoplasm of the serosal lining cells.

It has been shown by Dr. H. H. Woollard and Dr. G. B. Wislocki that through phagocytosis the hemal nodes are able to remove carbon particles that have been injected into the blood-stream of living sheep. Ordinary lymph-nodes show only traces of the carbon, although, if one lets the carbon reach them by their afferent lymphatics, they show a greater capacity to store it than do the hemal nodes. These investigators find that in the hemal nodes the carbon is lodged in coarse clumps within the cytoplasm of the large mononuclear cells. These conspicuous cells lie either free within the venous lacunæ of the node or in the lymphoid tissue surrounding the lacunæ. Less frequently they are found in the blood-sinuses. Very fine granules of carbon may be found in the cytoplasm of the reticular cells that form the meshwork of the blood-spaces. The spleen and liver, however, show a much greater power of removing carbon particles from the blood than do the hemal nodes, and it is interesting to note that the accessory spleens (cat and rabbit) possess the power to phagocytize carbon granules in the same degree as the spleen itself.

Clinical Importance of an Intact Peritoneal Mesothelium.

Dr. Cunningham has shown that by the injection of various mild irritants into the peritoneal cavity of the cat (if proper precautions are taken against sepsis and undue injury) it is possible to produce marked morphological changes in the mesothelial membrane without causing any adhesions. Apparently, no matter how much the mesothelial cells proliferate as a result of irritation, if the layer of peritoneal lining cells is complete it is sufficient to prevent the adherence of the two layers of peritoneum and thus prevent adhesions.

DEVELOPMENT OF INDIVIDUAL ORGANS.

Vascular System.

It will be noted that considerable attention has been devoted to the development of the blood-vessels, and it should be explained that our activities in this field date back to the well-known work of the late Professor Mall. The interest in the problems of blood-vessel formation which he inspired in his coworkers and pupils has led to a series of investigations that have given us a fairly clear conception of the developmental factors that control and modify this important system. While working in Baltimore, Dr. H. M. Evans, by means of his remarkable injection preparations, clearly demonstrated the primitive form of the vessels and the general principle of the manner of their change into the adult pattern. Later, Dr. Sabin, by utilizing the methods of tissue culture, succeeded in demonstrating the cellular origin of endothelium. She showed that certain mesenchymal cells are differentiated in situ into angioblasts which have two notable characteristics: (1) as they proliferate they adhere together in the form of islands or cords, which tend to unite with other cords, forming a plexus; (2) the central cells of these islands and cords for the greater part liquefy into plasma, whereas the peripheral cells are preserved as endothelium, the essential tissue of blood-vessels.

Having established the salient features of the differentiation of angioblasts, it became important to know how late in embryonic life this phenomenon continues. In the chick, Dr. Sabin has been able to demonstrate it for the first 7 days of incubation, a large part of the dorsal aorta forming in this way. On the other hand, in regeneration of blood-vessels in the adult, no evidence of differentiation of new angioblasts has ever been found. This brings us to the recent observations of Miss Ellen B. Finley, a worker with Dr. Sabin, who shows that in the human embryo angioblasts continue to differentiate from indifferent mesenchyme as late as the end of the second month of intrauterine life.

Differentiation of Angioblasts in the Human Embryo.

For determining how late in development of the embryo new angioblasts differentiate, Miss Finley chose, as a favorable place for study, the scalp region of human embryos between 20 and 30 mm. long. At this time the subcutaneous region at the top of the head is avascular and one can study the spreading upward of the growing vascular plexus of the scalp from the sides of the head as it invades the avascular tissues of the vertex. Miss Finley has shown how, in total mounts, the scalp may be spread out as a thin transparent membrane and all parts of the plexus studied under high magnifications and with the use of various stains. In this way she has demonstrated histologically the transition from avascular mesenchyme to the characteristic fringe of angioblasts, from this to the primitive capillary net, and from this in turn to the region of well-defined arteries and veins. Such preparations were controlled with sectioned material cut in various planes. Her studies establish the fact that differentiation of angioblasts in the human embryo is actively in process in specimens as large as 30 mm. long. As for the differentiation of the mesenchyme into angioblasts, she finds that it occurs at the tips of the growing plexus, perhaps due to the stimulus of the plexus on the mesenchymal cells lying close to them, and the new angioblasts usually are in direct contact with the tips. Through active proliferation they form large clumps, and almost at once hemoglobin-containing cells can be distinguished from bordering endothelium. Passing downward into the primitive capillary net, one finds that most of the hemoglobin-containing cells have disappeared, apparently having liquefied into plasma, and there are left only the fluid-containing endothelial tubes.

Growth of Veins by Sprouting.

In studying the vessels in the area vasculosa of the living chick, Dr. Sabin has been able to observe the process of sprouting in veins that had already acquired a considerable thickness of adventitia, a phenomenon pertaining to mature vessels and quite different from the process which Miss Finley studied. Solid endothelial sprouts appear to push their way between the adventitial cells as easily as through the looser tissue around capillaries. Furthermore, the sprouts were seen to grow out as veins, having a covering of adventitial cells. The establishment of this fact is of importance in understanding the repair of vessels after injury. That veins can regenerate as veins, without the preliminary development of a capillary bed, greatly increases the rapidity with which vessels can be renewed in wound-healing. This explains previous experiments in which Dr. Sabin showed that in intestinal anastomosis the vessels from one of the apposed surfaces of the intestine can be injected from the other surface on the fourth day after the operation. In the modifications that constantly occur in the vascular pattern, in addition to sprouting there is also destruction of branches. This could be observed in the living tissue. This process is characterized by a collapse of the endothelium, obliterating the lumen of the vessel, and this is followed by degeneration of both the endothelial and adventitial cells.

Vascularization of Bone-Marrow.

It is a comparatively simple matter to demonstrate by the usual injection methods the main blood-channels of the bone-marrow, and consequently the distribution and character of the nutrient arteries and the venous sinusoidal plexuses are quite well understood. This is not true, however, for the detailed ramifications of the smaller vessels and for the extent and continuity of the bone-marrow capillaries. These are so concealed by the bone-marrow cells that it has heretofore been impracticable to analyze them satisfactorily. Dr. C. A. Doan, using pigeons, has overcome this difficulty by depleting the marrow of its free cells through starvation. By combining starvation with carefully executed injection procedures, he has been able to demonstrate the existence of an extensive intersinusoidal capillary plexus which appears normally to be in a state of collapse, but which becomes distended under the conditions of the injection. The significance of this capillary bed as a possible source of new blood-cells is pointed out by Dr. Doan, and his specimens provide the anatomical basis for a reconsideration of the general question of hemopoesis in the adult organism. Differing from the spleen, the endothelium of the marrow constitutes a closed system, forming a continuous lining throughout all the vascular ramifications.

Although Dr. Doan, by his starvation experiments, was able to demonstrate the extensive closed capillary bed in the bone-marrow of the pigeon, one could not say that the same capillaries occur in mammals or deny the validity of the prevalent conception of an extra-vascular origin of red cells in the marrow of adult mammals. It proved impossible satisfactorily to reduce mammalian marrow by starvation or by several toxic agents. Dr. Cunningham and Dr.

Doan, working together, have found, however, that the marrow of rabbits can be depleted of its myelocytes by the intravenous administration of large doses of dead typhoid bacilli. In this way they have been able to demonstrate the intersinusoidal capillary plexus for mammals and have shown the probability that in the rabbit, as in the pigeon, red cells arise within the capillaries by proliferation of the endothelium, and that they enter the circulation through the capillaries into the sinusoids of the marrow.

Entrance of Small Lymphocytes into the Blood-Stream.

In my last report mention was made of the experiments of Dr. F. C. Lee, in which he ligated the thoracic duct by an intra-thoracic method, and of the lymphatico-venous anastomoses which he found to occur between the thoracic duct and the azygos vein. Continuing this work, he has studied the changes in the number of small lymphocytes in the blood-stream following such ligation in the cat, it being fairly well established that the thoracic duct is an important avenue for the entrance of small lymphocytes into the blood. Dr. Lee finds that ligation of this duct produces an immediate decrease, to the extent of 56 per cent, in the number of small lymphocytes, but that the preoperative level is again reached at about the end of three weeks. Having demonstrated the collateral circulation that occurs following ligation, it seems probable that we have here the explanation of the means by which the gradual return of the number of small lymphocytes to the preligation level takes place.

Development of the Aortic-Arch System.

As a result of the studies of Dr. E. D. Congdon and Dr. C. H. Heuser, we are now finally in a position to discard the Rathke diagram, which for over 70 years has dominated descriptions of the development of the aortic arches. Owing to the abundance of their material and the improvements in their technical methods, Dr. Congdon, working with human embryos, and Dr. Heuser with pig embryos, have been able to demonstrate every stage in the transformation of the aortic-arch system. It becomes clear from their observations that these vessels are not so much concerning themselves with carrying out a program of recapitulation as with following out a procedure in angiogenesis that is exactly like that prevailing in all other parts of the body.

There is first the differentiation of a given amount of endothelium and plasma. The endothelium is for the most part plexiform, but may exist as simple channels conforming to the available space and the character of adjacent structures. In the beginning its pattern bears no relation to any hydrostatic circulatory requirements, and this phase in its development can only be regarded as the laying down of an endothelial bed. As circulation begins, the endothelial bed is gradually modified into a system of suitable channels of supply and drainage for the surrounding structures, and one can then begin to speak of arteries, veins, and capillaries. These are simple while the structures are simple, and become more and more complicated as the latter become more elaborate. The pattern of the early blood-vessels shows every evidence of being almost entirely determined by the environment. Dr. Congdon and Dr. Heuser, by a remarkable series of adaptations, have given us a better description than we have thus far had of how the primitive pattern is modified into the final arteries and veins which are met in the adult, and they have also given a basis for a better understanding of the various vascular anomalies that occur in this region. Special mention should be made of the fate of the right dorsal aorta, which they show is almost completely taken up in the formation of the proximal part of the right subclavian artery, and they also show that one can not properly speak of a ventral aorta, either in the human or pig embryo.

Dr. Heuser's injections show very clearly the adaptive powers of endothelium in the case of the first pair of aortic arches when they surrender to the more caudal arches their original function of delivering blood from the heart to the dorsal aortæ. When this happens, they change from large trunk channels to a fine capillary net with suitable feeders and drainage communications, the same endothelium so reshaping itself as to meet only the requirements of the tissues of the first gill-bars.

Development of Pulmonary Vessels.

Dr. C. E. Buell has studied the origin and early stages of the pulmonary vascular system in the chick, basing his observations jointly on specimens prepared in serial sections and cleared specimens that had been injected with india ink under an improved technique. His description and well-selected illustrations carry the origin of these vessels back to stages earlier than have heretofore been shown, and their metamorphosis is traced through to the time the definite pulmonary vessels are laid down. One finds the same general sequence of events in the angiogenesis of this region that has been referred to above as occurring in other territories and with other organs. There is first the laying down of an endothelial bed or net. In this case a proliferation of angioblastic cells takes place from the endothelial wall of the sinus venosus opposite the beginning lung-bud, and perhaps it is added to by mesenchyme cells that differentiate in situ. Connecting strands of these vasoformative cells acquire a lumen and plasma by cytoplasmic liquefaction resulting in a capillary net along the surface of the primitive gut, an indifferent splanchnic plexus whose form expresses only endothelial growth and is not yet affected by the hydrodynamic necessities of supply and drainage. The second step is characterized by the development within this enlarging net of primitive pulmonary channels (favorable lines of blood-flow) which occurs on the completion of the lumen and the beginning of the circulation. There then follows the period of adaptation in which the vascular channels accommodate themselves to the growing lung and the circumstances of the surrounding structures, the arteries, veins, and capillaries being always adjusted in size and arrangement to the parts, progressively stage by stage, so that at any given time they are functionally adequate for that particular set of requirements, and no more.

Development of the Arteries of the Forelimb.

There are several good reasons for selecting the limb-bud as a region for studying the process of angiogenesis, namely, its structural simplicity, its accessibility for direct observation, and its relative isolation from the rest of the body and consequent freedom from environmental complications. Dr. H. H. Woollard has taken advantage of these circumstances and has completed a full account of the development of the principal blood-vessels in the forelimb of the pig. Starting at the time when there is first a definite capillary net, he has been able to demonstrate the second or circulatory phase in the angiogenesis of this region, that is, the enlargement and modification of certain parts of the net to form the primary arterial and venous channels. He has clearly shown how this is followed by a third phase, in which the primary pattern becomes gradually modified and adapted to the developing structures of the limb until the adult arterial pattern is attained. The arm-bud is not a favorable place to study the first phase, or origin of the endothelium, because of the dense character of the mesenchymal core. The nuclei of the mesenchyme cells are so closely packed that one can not satisfactorily observe the differentiation of the first angioblasts or the manner of their transition into capillaries. In Dr. Woollard's youngest stages there is a definite capillary net connecting by delicate feeders with all of the adjacent segmental arteries, and this, it may be mentioned, is the only trace of segmental character shown by the vessels of the arm. That the seventh segmental becomes the dominating feeder to the arm is attributed by him to the accident of its lying opposite the center of the growing limb-mass, and so receiving the maximum stimulus or physiological pull on the part of the capillary net.

NERVOUS SYSTEM AND ITS MEMBRANES.

Earliest Landmarks in the Human Embryo Brain.

For several years past Professor G. W. Bartelmez, in conjunction with Professor H. M. Evans, has been studying the external form and finer anatomy of the human embryo during the third week of development. Owing to the scarcity of normal and well-preserved specimens of this period, progress has been difficult and slow. Through the cooperation of several other laboratories, both in this country and abroad, it has been possible to complete a careful study of 14 embryos, ranging from 2 to 16 somites, and this has resulted in a large amount of important data and observations which are now being put in form for publication. Shorter communications have already appeared, and during the past year Dr. Bartelmez has published an account of the neural folds as they occur in these specimens. He has given us for the first time landmarks by which it is possible to trace the primary subdivisions of the brain from the time of the appearance of the somites. Being able to map out accurately those portions of the medullary folds that enter into the formation of the forebrain, midbrain, and hindbrain, respectively, as Dr. Bartelmez has made it possible to do, is, of course, of fundamental importance both to the embryologist and the comparative anatomist. The earliest landmark to make its appearance is a marked enlargement of the neural folds in the region of the otic plate. This constitutes the otic segment and is characterized both by its form and by the behavior of the neural crest arising from it. The second landmark is the midbrain, which forms the knee of the cranial flexure. Both of these are distinct as early as the 2-somite stage. Other landmarks appearing soon afterward are, to make mention of two, the distinctive behavior of the neural crest of the trigeminal segment and the unmistakable form and behavior of the cells of the first somite. On the basis of these definite boundaries, a significant interpretation is given of the rhombic and mesencephalic neuromeres. The analysis of Dr. Bartelmez clearly establishes the hindbrain as the dominant feature of the brain in its earliest stages, and thus places man in harmony with other vertebrates.

Absorption of Cerebrospinal Fluid into the Venous System.

The discovery of the physiological phenomena associated with experimental alteration in the salt content of the blood, referred to in previous reports, and certain new technical procedures, particularly a convenient method of recording the intracranial venous pressure, have rendered it possible for Professor L. H. Weed to make further contributions to our knowledge regarding the venous absorption of the cerebrospinal fluid. From his work it is clear that the normal process of absorption may well be merely the passage of the cerebrospinal fluid from the arachnoid spaces, a point of higher pressure, to the great dural sinuses, a point of lower pressure, through the cellular membranes of the arachnoid villi by simple filtration. Whether osmosis and diffusion are factors of importance remains an open question. When, however, a strongly hypertonic solution is injected intravenously, it is osmosis and diffusion that play the only active rôles, and, under the influence of the marked osmotic pull of the blood, water is attracted into the blood-stream from every available source. Absorption takes place from the perivascular spaces into the capillary bed of the nervous system and through the ependymal lining of the cerebral ventricles into the subependymal capillaries, as well as through the normal pathways of absorption in the arachnoid villi. Where there is marked cellular differentiation, as in the epithelium of the choroid plexuses and in the mesothelium lining the arachnoid spaces, the processes of osmosis and diffusion do not function even with an extraordinary increase in the salt content of the blood.

These investigations were carried out on living animals (dog and cat), and the experiments were so conducted that simultaneous records were made of the intracranial venous and arterial pressures, the systemic venous pressure, and the pressure of the cerebrospinal fluid. The record and accurate control of these pressures made it possible for Dr. Weed to study the process of absorption under known physiological conditions and to effect replacement of the cerebrospinal fluid with true solutions and suspensions of particulate matter adapted to the histological tracing of the pathway taken by this fluid in its return to the blood-stream, without the alteration of any of the normal pressure relations.

Arachnoid Granulations in the Spinal Region.

It has been shown by Dr. Robert Elman that some cerebrospinal fluid, though very small in amount, probably escapes into the blood-stream and possibly into the lymphatics throughout the spinal region at the exit of the nerve-roots. In the angle where the arachnoid membrane is reflected over the emerging spinal nerve-roots, Dr. Elman finds clusters of proliferated arachnoid cells which appear to be analogous to the arachnoid granulations in the head and which have been repeatedly referred to in connection with the studies of Dr. Weed. He has demonstrated that suitable fluids, when injected into the subarachnoid space, escape through these cell-nests and make their way into the veins outside of the dural sheath. He finds no evidence of the existence of any other physiological pathway connecting the arachnoid with the tissues peripheral to the vertebral canal. Aside from the relatively minute amounts absorbed through the spinal arachnoid cell-clusters, the only flow of the spinal fluid must therefore be headward toward the large cerebral sinuses. The observations of Dr. Elman are of immediate importance clinically, because of their bearing upon the problem of transmission of infection to the spinal cord.

Innervation of the Facial Musculature.

The morphological studies of Dr. Ernst Huber upon the facial nerve and facial musculature in the dog have appeared in two parts during the past year. This work was started in the University of Zurich, and, since his association with the Johns Hopkins Medical School, Dr. Huber has continued his program of a broad comparative study of this nerve-muscle group and has extended it to the negro. In cooperation with Dr. Walter Hughson, he has been able to confirm his morphological observations on the innervation of the facial musculature by experimental studies in the cat and dog. In narcotized animals the facial musculature was laid bare and the nerve branches were stimulated with a weak electric current and the respective contractions recorded. In other animals the different branches of the facial nerve were sectioned, after which the resultant paralysis was determined, and in these animals the investigators were able to demonstrate resultant degeneration in the facial-muscle groups belonging to the different branches.

GENITO-URINARY ORGANS.

Development of Kidney in Chick Embryos.

A striking example of the desirability of combining the study of living tissues with that of fixed serial sections, where one is studying the development of an organ, is afforded by the important results that were obtained in this way by Dr. W. F. Rienhoff, in his work on the development of the metanephros in the chick and which have made it possible for him to give a very complete account of this morphogenetic process. He made spreads of living tissue taken at different stages of development, and also transferred small pieces of the kidney primordium to a culture medium, and, after incubating them for varying lengths of time, studied them both in the living state and after fixation and staining. For certainty in orientation, these were then compared with the same structure as seen in serial sections. In this way he was able to demonstrate the high degree of specificity that exists in nephrogenic tissue. The small transplanted particles tend to acquire their predestined form, regardless of the foreign environment and the absence of pressure of surrounding structures; the collecting tubules grow in a straight line and the secreting tubules always become convoluted. Dr. Rienhoff was able to observe every step in the development of the glomerulus, which has heretofore been one of the puzzles for the embryologist. Together with its capillaries and blood elements, it differentiates in situ from the cellular mass that makes up the distal end of the convoluted tubule. It is not invaginated like a cup, with an ingrowth of capillaries, as has been generally supposed; the lumen forms within the cell-mass by virtue of a rearrangement and separation of the cells, which leaves a thin layer of epithelial cells (Bowman's capsule) on one side and a mass of epithelial and endothelial cells on the other (glomerulus). The form of the convoluted tubule is the result of the differential growth of its component cells, its various bends and curvatures not being simply accidental. As the lumen forms, it is possible actually to observe the uniting of the convoluted and collecting tubules which occurs at a definite place. The blood system surrounding the metanephric tubules is at first principally sinusoidal, the circulation taking place by diffusion between the sinuses and peripheral capillaries, as in the pronephros and mesonephros. From the first the tubules are completely enveloped in an endothelial membrane. Later, the sinusoidal system is almost entirely replaced by capillaries, and direct continuity is then established with the peripheral system.

Development of the Male Perineum.

In young embryos a deep peritoneal pouch extends down to the floor of the pelvis, separating the rectum from the prostatic region of the bladder. This rectovesical pouch subsequently becomes obliterated to the extent of allowing the rectum and prostate to come into contact, separated only by the so-called Devonvillier's fascia. Because of its importance in prostatic surgery, Dr. M. B. Wesson has studied the embryology of this fascia and has been able to demonstrate the important fact that it is not formed simply by fusion of the two layers of fetal peritoneum, as had been generally supposed. It is true that the layers of peritoneum do fuse, but they are absorbed and disappear before the differentiation of this specific fascia occurs. This fascia arises as a membranous condensation of connective tissue in the mesenchyme of the recto-prostatic space. Instead of an embryonic peritoneal remnant, it is a new structure, somewhat similar to the bursal formations that are found in many parts of the body where there is a gliding of adjacent structures, and so notably developed in the case of the bulbar fascia of the eye. Coincidently, it has the important clinical function of serving as a barrier in cases of extravasations of urine and against the spreading of infections and of malignant growths. In this investigation the musculature of the perineum was carefully studied, particularly the development and ultimate anatomy of the recto-urethralis muscle.

HUMAN EMBRYO OF 20 PAIRED SOMITES.

In studying the anatomy of embryos, one usually confines his attention to one organ at a time, tracing it through the various steps in its development for all possible stages. But it is also well at times, and particularly in young specimens, to study the embryo as a whole and carefully determine the correlative development of all the parts. There is thus obtained a cross-section of the growth process at a particular stage. We have published four such studies in the Contributions to Embryology. A fifth study has just been completed by Professor Carl L. Davis, of a human embryo of 20 paired somites.

This embryo was studied with particular care because, due to its exceptionally good state of preservation, it constitutes a perfect representative of this important stage in development, just after the anterior neuropore has closed and when the primitive gut begins to subdivide into definitive organs. This is the youngest stage in which the lung primordium has ever been recognized.

GROWTH OF THE NEGRO AND WHITE FETUS.

The investigations upon body proportions during fetal growth have been continued by Dr. A. H. Schultz and are now completed for the extremities and the trunk. The head measurements have been taken, and as soon as their analysis is completed it is planned to have the entire study issued as a monograph. Preliminary accounts have already been published by Dr. Schultz, in which he points out that most racial differences exist as early in fetal life as the human characteristics can be recognized, and that variability in fetuses is fully as high as in adults. As will be remembered from last year's report, this was also found to be true in my study of the development of the external ear. Dr. Schultz further shows that asymmetries do not begin with childhood, as has been assumed, but can be recognized with certainty from the fourth month of intrauterine life. Among the interesting details of development that were discovered, mention should be made of the following: The umbilicus shifts to a relatively higher and the nipples to a relatively lower position on the trunk in the course of growth. Compared to the height of the trunk, the limbs grow very rapidly until the end of the fifth month, whereafter their growth slows down, so that at birth the extremities are again relatively shorter. The forearm grows faster than the upper arm and the leg faster than the thigh; in negroes both forearm and leg are relatively longer than in whites. The thumb becomes relatively shorter with advance in development, but, as might be expected, it is at all stages slightly longer in whites than in negroes. The hand, as well as the foot, is relatively broader in early than in late fetal life, and both are broader in whites than in negroes. In man the great toe becomes relatively longer and the other toes relatively shorter during development, whereas in these points the ontogeny of other primates behaves in just the opposite way. As for the head, it may be said that the cephalic index decreases with advance in development. The face grows faster than the cranial part of the head and is larger in negroes than in whites.

PHYSIOLOGY OF REPRODUCTION.

Cyclic Changes in the Tubal Epithelium.

The interesting observation has been made by Dr. F. F. Snyder that, during the œstrous cycle of the pig, the epithelial tissues of the Fallopian tube pass through a series of alterations closely resembling those exhibited by the epithelium of the uterus, which were described by Dr. Corner and mentioned in my last report. During œstrus, while the ova are passing through the tubes (first three days after ovulation), the epithelium is more than twice as high as during the period of implantation in the uterus (second week after ovulation), and during the third week, with the return of œstrus, it gradually regains its maximum height. While the epithelium is highest, the underlying stroma shows its participation in the process by its swollen and edematous condition. Coincident with this periodic rise and fall in the height of the epithelium, there is an alternate appearance and disappearance of the characteristic cytoplasmic projections of the non-ciliated cells, the projections disappearing as the epithelium becomes higher. Just why these changes should occur in the tubes remains obscure. In the uterus it seems probable that they take an active part in the mechanism of implantation, and it is possible that the tubal reaction is merely due to the embryological fact that the tubes are derived from the same primordium (Müllerian ducts) that forms the uterus. Compared with the ovarian phases, the decrease in height of the tubal epithelium and formation of the cytoplasmic processes is synchronous with the growth and full development of the corpora lutea, and in the event of pregnancy the epithelium remains in this state, further alteration apparently being inhibited. Dr. Snyder finds that the ciliated cells of the tubal epithelium show no alteration, either in distribution or activity, at any period of the œstrous cycle, which is further evidence that they play no rôle in the migration and implantation of the ova.

Cyclic Changes in the Smooth Muscle of Uterus and Tubes.

Supplementing Dr. Corner's studies on the cyclic changes in the ovaries and uterus of the sow, Mr. J. D. Keye, for the uterus, and Mr. D. L. Seckinger, for the Fallopian tube, have found that periodic variations occur in the spontaneous rhythmic contractions of the smooth muscle of the genital tract and that these variations bear a definite relation to the œstrous cycle and early pregnancy. They discovered this variation in rhythm by suspending in oxygenated Locke's solution strips of muscle from specimens representing various stages of the cycle and recording their contractions by means of a kymographion. From Mr. Keye's observations we find that during the time the Graafian follicles are maturing, and for a short time after they rupture, the rhythmic contractions of the smooth muscle of the uterus are, for the most part, of relatively large amplitude and of long duration (1.5 to 2.5 minutes). Superimposed upon these are minor waves of higher frequency, and as the cycle advances from one œstrus, through the interval, to another (from the third to the twelfth day of the cycle) the minor waves gradually replace the major waves until about the fifteenth day, when the major waves begin again, reaching their maximum with the enlargement of a new crop of Graafian follicles. Pregnancy definitely alters the type of cyclic contractions. As early as the sixth day of pregnancy Mr. Keye observed a marked diminution in both types of waves, the minor type apparently entirely disappearing.

The smooth muscle of the tube presents an alteration in rhythm that is still more marked than that of the uterus. Mr. Seckinger finds that during the period of œstrus, and while the ova are still in the tube, the tubal contractions are characterized by their rapidity (13 to 15 per minute) and by undulating variations in amplitude. As the ova reach the uterus, the tubal contractions drop in frequency to 5 to 10 per minute and lose their undulating character, and this inter-œstrous type continues until the nineteenth day, when the œstrous type is resumed. Mr. Seckinger finds that the change from the inter-œstrus to the œstrous type of contraction takes place at a definite time, namely, when the new follicles have attained a diameter of 7 to 8 mm., and it is a significant fact that it is just at this time that the cells of the theca interna of the Graafian follicle undergo marked histological changes indicative of secretory activity. Pregnancy does not appear to have any effect upon the type of contraction of the tube, the contractions remaining identical with those of the inter-œstrous period. Both Mr. Keye and Mr. Seckinger point out the possibility that the variations in these muscular contractions may be the active agency in the transportation of ova and early embryos to their final position for implantation in the uterus.

Permeability of the Placenta.

In view of the considerable difference in the structure of the placental barrier, as found in the cat and the rabbit, Dr. R. S. Cunningham has extended his studies on placental permeability to the latter animal. He has been able to demonstrate that in the rabbit both sodium ferrocyanide and iron ammonium citrate pass from mother to fetus, though sodium ferrocyanide passes the placental ectoderm somewhat more easily, being found in the fetal blood before the citrate and being present in greater concentration. Since the placental barrier in the rabbit is of a simpler type, one might well expect a decreased amount of placental control. Nevertheless, some control over and above the ordinary laws of osmosis and diffusion does exist, even in this simple hemo-chorionic type.

PATHOLOGY OF THE FETUS.

Intrauterine Mortality in the Pig.

In the Year Book for 1921 I gave an account of Dr. G. W. Corner's observations upon the striking histological alterations that are shown by the uterus during the definite periods of the œstrous cycle. This information has enabled Dr. Corner to test more exactly the condition of uteri bearing abnormal and dead embryos, and whether the failure of these embryos to develop can be attributed to their environment.

If we are to eliminate the environment as a causal factor, the existence of these functional changes makes it necessary to determine not only whether the uterus is simply free of infection and gross pathological change, but also whether it has reached the particular stage of its histological cycle necessary for implantation and nourishment of the developing ova.

For the purpose of answering this question, Dr. Corner studied 535 pregnancies in the domestic sow at all stages of gestation; in each case the number of ova discharged at the ovulation which led to the pregnancy under consideration was determined by count of the corpora lutea; the number of embryos present and the number missing were ascertained; abnormal embryos were counted and studied, and as far as possible all abnormalities were correlated to the histological condition of the uterus and of the corpus luteum. Separating his specimens into three groups, he found that in late pregnancy (151 mm. to term) 28 per cent out of a total of 1,265 ova had failed to develop, and of those that developed nearly 2 per cent were abnormal. In the middle period of pregnancy (41 to 150 mm.), of 1,909 ova about 20 per cent failed to develop, and of those that developed 0.47 per cent were abnormal. In early pregnancy (8 to 40 mm.), of 1,306 ova 20 per cent were already missing, and of those that developed 2.2 per cent were abnormal. The commonest type of abnormality met with in these cases was that due to death and maceration, and in the early stages it resulted in complete disintegration of the embryos and membranes; in the later stages the fetus persisted, but became transformed into a mummified mass. In many cases the dead embryos in a single uterus were of widely different dimensions, indicating that death occurred at different stages of pregnancy. Furthermore, the macerated embryos were in most cases much smaller than the normal embryos in the same uteri, indicating long persistence of the macerated specimens in the uterus. It was found that the uterine wall overlying these dead embryos was always normal, both macroscopically and microscopically. Since these specimens cover the whole period of implantation, there is no evidence in the pig that faulty implantation is a cause of embryonic mortality and abnormality, but there is much to indicate that embryos may become abnormal in spite of a uterine environment which, by all the criteria at our present command, is both anatomically and functionally normal. It is of interest to note that about 10 per cent of the ova never segment, about 10 per cent degenerate after becoming blastocysts, and that 5 to 10 per cent become abnormal during the subsequent course of pregnancy, leaving about 70 per cent that develop into living pigs.

Faulty Environment and the Human Fetus.

The majority of investigators who have studied abnormal embryos have laid stress on environment and faulty implantation as causes of defective development. It is to be remembered, however, that they have worked under the difficulties linked with scarcity of material and that the cyclic histological changes of the human genital tract are very imperfectly known. This laboratory was fortunate in recently receiving a specimen which appears to me to have a significant bearing upon this general problem and which, in conformance with Dr. Corner's investigations, indicates that abnormalities of development in man are to be frequently attributed to factors influencing the early ovum rather than to the environment at the site of implantation. The specimen consists of a fetus which died at about the twentieth week and, being retained in the uterus, thereafter underwent maceration and alteration in form. The attached placenta showed a correspondingly marked degeneration. The whole picture is one commonly met with in abortion material. That the environment was not the cause of defective development in this case is proved by the circumstance that it was a double-ovum pregnancy in which the other ovum went through to term as a normal living baby. The normal and abnormal placentæ are directly contiguous and so must be regarded as exposed to essentially the same surface and environment. At their junction there is an abrupt demarcation, on one side of which the villi are in an advanced stage of fibrinoid degeneration, while on the other they are entirely normal.

Whereas we have seen that ova may result in defective embryos in spite of a normal environment, it is also true that under some circumstances an ovum may develop normally in an abnormal environment, as is shown in ectopic pregnancies. A unique case of this kind was reported by me during the past year, in which a human ovum became implanted and underwent development entirely outside of the abdominal cavity, in the superficial fascia of the abdomen, forming a tumor just under the skin. In spite of this abnormal environment, at the time of its removal the ovum had reached the size of a hen's egg, and both the embryo and chorionic sac were normal. The case was one in which a ventral fixation of the uterus had been performed and, through mistake, the Fallopian tube had been pulled through the rectus abdominis muscle, which presented a pathway by which the ovum reached its unusual implantation site.

Whether abortions and defective development are due to environment (faulty implantation) or to the composition of the germ-plasm is a matter of great clinical importance, for knowledge on this point must be had before intelligent treatment can be administered. This problem has been studied by Dr. J. L. Huntington, who has reported on 398 cases of pregnancy, of which 39 were terminated before the end of the twenty-eighth week. Of these, 27 were cases of inevitable abortion, in most of which the lifeless embryo had been retained from three to eight weeks before its expulsion. In these cases it was apparent that germinal defects played a greater rôle than disease of the genital tract. Dr. Huntington points out the importance of determining the size of the uterus as early in pregnancy as possible, and where there is bleeding without adequate uterine enlargement, to assume the death of the fetus and permit the emptying of the uterus through its own contractions or, if necessary, accomplish it by operative procedure.

Abnormal Development of the Hindgut.

Dr. J. C. Baldwin has studied the morphology of a fetus with entero-urethral fusion in which there was an enormous distention of the bladder. So great was the consequent enlargement of the abdomen that the case was mistaken for one of fetal ascites. In addition to the localized anomalies in the region of the hindgut, it is significant to note that the fetus showed definite evidences of death at about the fourteenth week and prolonged intrauterine retention. In view of the preceding paragraphs, this may safely be regarded as an example of defective germ-plasm.

FORMATION OF MONOCHORIONIC TWINS.

It is only in the past few years that we have begun to emerge from the realm of pure conjecture as to the mechanism of origin of identical twins, and this is because of the scarcity of early material. Fortunately, Dr. G. W. Corner, in examining the uterine contents of a large number of pregnant swine, was able to find three important stages in this process, and thus part of our hypothesis is replaced by direct observation. From his specimen it is clear that such twins arise within a single blastocyst, although it still remains possible that monochorionic twinning may result from the fusion of separate blastocysts with obliteration of the intervening trophoblastic wall. He further shows that twinning in the pig may occur before the formation of the amnion, and in this respect it is quite different from the armadillo, the form on which our most complete descriptions were based. Because of the late formation of the amnion in that order, the possibility of monochorionic twinning in ungulates has been regarded by some writers as impossible. Dr. Corner includes in his study a clear account of the development and arrangement of the amniotic and allantoic membranes. It may be added that, as I write these lines, I have before me a still earlier stage that completely substantiates and amplifies Dr. Corner's observations, and in my next report I shall make occasion to refer to this subject again.

DEPARTMENT OF GENETICS.[1]

C. B. Davenport, Director.

GENERAL STATEMENT.

In this Department the year ending August 31, 1923, has been productive of a variety of interesting results. On the purely experimental side progress has been made in the induction of mutation, in the further analysis of chromosome variation in relation to somatic variation, in ascertaining the external factors that modify the sex-ratio in *Cladocera,* and in unraveling the complicated interrelation of the internal secretions that influence fecundity.

In the field of human genetics progress has been made in analyzing the hereditary factors that help determine body build and bone defects and in determining relative values in the national population of the different racial elements contributed to it by immigration.

Of all our work, that which seems most fundamental is with the chromosomes. When in 1885 Weismann first used the term germ-plasm to signify the totality of the chromosomal complex characteristic of an organic species, the new term with its implications must have seemed, even to many biologists, unwarranted and speculative. To-day it is perhaps the principal object of investigation in genetical research and the chromosome has been raised from an exceptionally esoteric and technical position to one of acknowledged utmost importance to man and all of his interests. Gradually the conception is forcing its way that we are, under ordinary conditions of environment, "what our chromosomes make us."

This germ-plasm Weismann regarded as singularly protected from environmental influences, and certainly recent experience has fortified this conclusion. Nevertheless, change (evolution) does occur; the chromosomes do change. A minute change in the gene constitution of a chromosome, and still more the addition or subtraction of a single chromosome, will ordinarily be associated with a uniform and definite change in the soma. That change is, obviously, in part due to peculiarities in the constitution of the organism itself, but it is now quite certain that it is possible, by abnormal conditions of temperature, by the X-ray, probably also by alcohol, sera, centrifuging, and other conditions, to modify not only the processes of cell division and chromosome separation, but also the composition of the individual chromosome. This is, certainly, induced or directed evolution.

While the immediate consequence of such induced mutations is not always a new species, with its properties of multiple differentiating characters, inter-sterility, and constancy of traits, there is one class of inducible mutation that meets these conditions, as Dr. Blakeslee has pointed out. That is the class of tetraploidy, in which the number of chromosomes is doubled. Following out this suggestion, Dr. Belling has investigated a number of plant species and finds that in one of them the chromosomes are, indeed, four of a kind, leading to the inference of the origin of this species by tetraploidy—i. e., the failure, somewhere in its history, of the divided chromosomes in some parent cell to get into distinct daughter nuclei. In consequence of this failure the number of chromosomes in the nucleus is permanently doubled. Furthermore, the resulting new form meets the above-named criteria of a species.

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[1] Situated at Cold Spring Harbor, Long Island, New York.

Admitting this to be a real method of species origin, the question of the origin of species is far from being answered. But our experience so far justifies us in concluding that the question of the origin of species is at basis that of the origin of changes in the chromosomes; and the question of evolution is, in part, that of the evolution of the chromosome complex and, in part, that of adjustment to environment, in which the environment acts as the ruthless selector.

Even had we learned the various internal and external influences that control chromosomal changes we should be far from having a complete insight into genetics. The question would still be urgent, How do the determiners or genes of the chromosomes work out their destiny in particular somatic traits? Into this matter we are gaining some insight by studies on the rôle of hormones in development and, indeed, by the various analyses of the genetic elements of adult traits.

Twenty years have passed since this Department or its predecessor (that of Experimental Evolution) was founded. One of the appointees of the first year was a cytologist, a recognition of the importance of the cytological basis of genetics. During this period, which nearly coincides with that of the modern development of genetics, the chromosome has come ever more and more into the foreground. The next new developments are, doubtless, those of biological physical chemistry, a discipline in which little research has yet been done. But until research is pushed in this field we shall not know the relation between the chromosomes and the processes of general growth and differentiation, which are the essence of that development of which heredity is the control.

DETAILED REPORTS ON CURRENT INVESTIGATIONS.

INTERCHROMOSOMAL MUTATION.

The reports of the past few years have recorded in detail the rise and progress of our research on the relation between the extraordinary irregularity of the karyokinetic phenomena in the formation of gametes in the jimson weed (*Datura*) and the equally rare variability in the somas of these plants. To learn all of the somatic changes induced by the chromosomal irregularities requires the cooperation of persons with special technical knowledge in different fields, and this cooperation we have been able to obtain from university men who have come to us for the summer months. The resident group in these experiments is composed of Dr. A. F. Blakeslee, who has directed them from the beginning; Dr. John Belling, who is making cytological studies and has had the temporary assistance of Misses Elizabeth Lord and Rachel Haynes; Mr. M. E. Farnham and his successor, Mr. Gordon Morrison, who have had immediate charge of most of the work in the greenhouse and field. The visiting collaborators have again been Professor E. W. Sinnott, of the Connecticut Agricultural College at Storrs, who has been studying the anatomy and histology of the mutants; Professor John T. Buchholz, of the University of Arkansas, who has continued his studies of the differences in the growth of the pollen-tubes of different daturas in the pistils of *Datura* mutants; and Mr. J. L. Cartledge, of the University of Pittsburgh, who has been engaged in pollen counts and assist-ing in other ways. Misses Bergner and Watt, of this Department, have assisted in hybridization and counting pollen.

Trisomic Types of Mutants: Primary and Secondary.

Two of the most interesting developments of the work with *Datura* are the discovery of the differentiation of the simple trichromosomic types into primary mutants and their respective varieties and the attempt to determine the causes that lie back of such differentiation.

Dr. Blakeslee reports on this matter as follows:

"It was stated in our last report that, whereas there should be only 12 ($2n+1$) mutants expected if each mutant is caused by the presence of an extra chromosome in a different one of the 12 chromosomal sets, as a matter of fact we have over 20 mutants with a single extra chromosome. It has been possible to arrange the mutants in not over 12 groups. Six of these groups have as yet only a single member, but in the other groups we have a main mutant and one or more varieties. We have sometimes termed these 'apostles' and 'acolytes.' The following is some of the evidence for connecting a main mutant with its variety: (1) Similarity in external appearance; (2) similarity in internal anatomy (Dr. Sinnott has successfully grouped the mutants from study of their anatomical structure without knowing how we had classified them from other evidence); (3) a study of chromosome size in mutants is being made by Dr. Belling and should give further evidence, positive or negative, on the grouping of mutants; (4) the main mutant and its variety in one group (Poinsettia-wiry) give the same trisomic ratios for a Mendelian factor, apparently carried by the extra chromosome; (5) so far as our records have been tabulated, it seems to be true that the variety regularly throws a small percentage of its main mutant in the offspring, while the main mutant does not throw its variety except very rarely.

"As to which in the group is to be considered the main mutant and which the variety is shown by the breeding behavior just mentioned, as well as by the fact that the main mutants occur spontaneously from normals more frequently than their varieties, and especially by the fact that the main mutants are (with only one certain exception) the only ($2n+1$) types so far thrown by triploid ($3n$) plants. Since in triploids each chromosomal set is a trisome and the assortment of its members is at random, we should expect, among the viable combinations of chromosomes in the offspring, the 12 main ($2n+1$) mutants. Out of 784 offspring from triploids, 248 have been normals, 112 double mutants, and 424 ($2n+1$) mutants. Of these latter, 51 were Globe, 39 Poinsettia, 38 Cocklebur, 37 Ilex, 18 Echinus, 24 Rolled, 41 Reduced, 57 Buckling, 32 Glossy, 32 Elongate, 50 Microcarpic, and 2 Spinach. None of the varieties appeared in the triploid offspring, with 1 certain exception and 2 uncertain determinations. We feel confident that we have in the above list at least 11 of the 12 main mutants. The relatively poor viability of Spinach may account for the small number of this type, but the Spinach group is anomalous in certain respects and shows possible relationships to another group.

"For some time our efforts have centered upon the relation between the main mutants and their varieties. Our preliminary hypothesis, that the variety might be a main mutant modified by a Mendelian factor, has been shown untenable by an extensive series of breeding-tests. What may be the clue to the situation was obtained this last winter in the breeding behavior of the group of mutants consisting of Cocklebur and Wedge, the latter by various tests shown to be a variety of the former. Previous evidence indicated strongly that Cocklebur has its extra chromosome in the set carrying the genes for armed or *inermis* capsules on account of the ratios which it throws when heterozygous for these factors. A selfed heterozygous plant of the variety Wedge threw a 3 : 1 ratio, which is typical of disomic inheritance and seems to indicate that there are in this $(2n+1)$ variety only two chromosomes carrying genes for armed and *inermis* rather than 3 as expected. More data are desirable, but offspring from selfed and back-crossed parents now in the garden seem to confirm the tentative conclusion from the winter's cultures. Our preliminary hypothesis is that the variety may have a part of one of the chromosomes in the trisome deficient (in this group for the armed-*inermis* genes), either by inactivation of this part or by an actual loss of a portion of the chromosome. A tentative scheme of the possible chromosomal behavior has been worked out which squares measurably well with the differences observed between the Cocklebur mutant and its variety Wedge in respect to the inheritance of Mendelian factors and in respect to the fact that the variety regularly throws the main mutant, while the latter rarely throws the variety. The scheme is merely a tentative working hypothesis, however, since it is susceptible of various tests, especially from segregation of Mendelian factors and from the cytological relations. Dr. Belling is undertaking a detailed study of the size relations between the main mutants and their varieties and, if our preliminary hypothesis be correct, should soon determine whether or not there is actually a shortening of the extra chromosome in the varieties instead of a deficiency unrepresented by any morphological difference, as seems to be the condition in reported cases of deficiency in *Drosophila*. The relatively few varieties to each main mutant (generally less than one) speak for a definite region of fragmentation.

"It has been previously mentioned that the Spinach group showed possible relationships to another group. It is also true that the proportion of unrelated mutants thrown by this group is unusually large. The most extreme example is a culture this summer derived from a cross between the two members of the Spinach group. Out of 161 offspring, 95 (nearly 60 per cent) were mutants of various types. The cause of such anomalous behavior is being studied further, both from the cytological and the breeding standpoints. The evidence from the Spinach group, however, indicates that it will be unsafe to apply, without modification, our hypothesis for varieties to all our $(2n+1)$ mutants.

"In an early stage of our study, when we had only 12 $(2n+1)$ mutants, which number was to have been expected on the basis of an addition of a single unaltered chromosome to the constellation of 12 diploid pairs, it seemed that a method was opened up for an analysis of the chromosomal constitution by the unbalancing effects produced when a given extra chromosome was present. The finding of more than 12 $(2n+1)$ mutants made any attempt at an extensive analysis of this kind unwarranted. With the discovery, however, that the main mutants (at least 11 of the 12) can be distinguished from their varieties, the possibility of such an analysis is restored, and, if deficiency, fragmentation, or other alteration of chromosomes proves to be a means of modifying mutants into varieties, we have an additional method of analyzing the chromosomes by studying the unbalancing effect of the assemblage of factors in the fragments. Already, from only a superficial study of the main mutants and their varieties, we can conclude that each of the chromosomes contains factors which affect the somatic characters of habit of growth and of intensity and distribution of purple pigmentation, the various mutants varying in plus or minus direction from the balanced condition in normal diploids. Dr. Sinnott is analyzing the effects of extra chromosomes upon the internal anatomy and Dr. Buchholz the effects upon pollen-tube growth.

"The effects of chromosome differences upon the biochemical product should soon be studied. For such work we are getting together what we believe is the most nearly comparable material ever used in plant breeding. From our first haploid (plant A) in line 1, we have obtained diploids by non-reduction which (barring new mutations) must be absolutely homozygous. It has been our effort ultimately to get all our mutants into this homozygous 1A line and we have already succeeded with the tetraploid ($4n$) and the majority of the main ($2n+1$) mutants. We are now crossing the $4n$ with $2n$ plants in this line and should within a few months have triploids ($3n$) which should throw the main mutants. The latter, with sufficiently large numbers of offspring, should give rise to the mutant varieties.

"We are obviously in need of Mendelian characters with which to tag the individual chromosomes and parts of chromosomes and are trying to locate in their respective chromosomes some 6 or 8 Mendelian factors which we have isolated from our main lines or from new mutations. We have succeeded in hybridizing our *Datura stramonium* with the distinct species *Datura ferox*, and in later generations hope to isolate a number of Mendelian characters from this species cross. In addition, we are planning to sow seed from a large number of selfed parents in line 1A, with the hope of getting new gene mutations recognizable in the seedpan."

OTHER MUTANT TYPES IN DATURA.

The occurrence of haploids has been shown to be probably due to a process of true parthenogenesis of the reduced egg. An *inermis* haploid was obtained from a cross between a female parent heterozygous for armed and *inermis* and a pollen parent homozygous for armed. Further, two haploids have arisen from the cross *D. stramonium* × *D. ferox* and resemble in all visible respects the *D. stramonium* parent. In these three cases apparently the male gamete did not enter in any way into the constitution of the haploid offspring. Parthenogenesis has been observed not infrequently in tetraploids when they are crossed with pollen from diploids. By using recessive white tetraploids as female parents and pollen from purple diploids, the white diploids which resulted could be assumed to have originated from the tetraploid parent alone. The purple offspring from this cross have all been triploid.

It has previously been shown that in addition to the usual disomic ratios obtained when the chromosomes are in twos in the set heterozygous for a given factor, distinct trisomic ratios are obtained when these chromosomes are in threes, as in ($2n+1$) mutants; and tetrasomic ratios when they are in fours, as in tetraploids. This season we have obtained the first pentasomic ratio from a ($4n+1$) *Poinsettia* parent heterozygous for purple and white flower-color.

The findings of the past year show that chromosomal aberrations are a not unexpected cause of sectorial chimeras in *Datura* and may account for the reported bud sports in other species. Four plants have been found in our cultures with a branch which bore leaves of a distinct character. In two of these cases, Dr. Belling has found the abnormal branch to be a chromosome deficiency of the type ($2n-1$), so far as the pollen mother-cells is concerned. The two other plants have not as yet been studied cytologically, but from appearance can be provisionally placed in the same category. The deficiency does not appear to be transmitted to the offspring. The deficiencies just mentioned have been parts of a plant otherwise apparently normally diploids. A single plant has been discovered, however, all the branches of which bear abnormal leaves and almost entirely sterile flowers. Dr. Belling reports the pollen mother-cells of this plant apparently to be ($2n-1$).

Sectorial chimeras appear to be a not infrequent stage in the production of tetraploid races. In 3 plants otherwise diploid, a branch was found to be tetraploid ($4n$), as indicated by pollen-size. The growth of these $4n$ branches was slow and buds were not secured for chromosome counts, but seeds from the $4n$ branches produced $4n$ offspring, while seeds from the $2n$ branches produced $2n$ seedlings. Tetraploids frequently first appear in a peculiar rough-leaved form in which patches are devoid of palisade parenchyme, and it is possible that, in addition to the sharply defined sectorial chimeras, periclinal chimeras and chimeras with a less orderly mixture of chromosomally distinct tissue may occur in *Datura.*

Rate of Pollen-Tube Growth in Datura Mutants.

Irregularities in some proportions obtained in certain crosses between the varieties of *Datura* have led to a study, by Professor John T. Buchholz, of the relative rate of pollen-tube growth of different varieties, following along the lines of an hypothesis suggested by Correns. This study, made during two summers, has yielded important results described by Dr. Buchholz as follows:

"A study of the germination and growth of normal pollen on the stigmas of a dozen or more simple trisomic mutants of *Datura* on cut flowers under comparable conditions (about 18° to 19° C.) has shown that there is no great difference in the depth of penetration of the pollen-tubes in the different cases, though it is somewhat slower as a rule for most of the mutants. Stigmas of normal plants were used under the same conditions for the germination of the pollen of 18 of these ($2n+1$) chromosomal mutants, with the result that the pollen differed widely in the percentage of its germination, as well as in the depth of penetration of the pollen-tubes. The pollen-tubes having n chromosomes from each mutant penetrate to about the same distance as normal pollen-tubes, while there seems to be a distinct group of slower pollen-tubes, presumably those having the ($n+1$) chromosomes, which either fail to germinate or lag behind. In a few of the mutants, such as Sugarloaf, for example, there seems to be a distribution of these pollen-tubes into three modes, suggesting the possibility that there may be more than two classes of pollen produced, while pollen-tubes from normal plants are distributed essentially in a unimodal curve.

"Considerable attention was given to a preliminary study of the physiology of pollen-tube growth in normal plants. Pollinations with second batches of pollen applied to used pistils after intervals of 1, 2, and 3 days show that the second pollen-tubes are retarded to about two-thirds to one-half of the growth-rate of the same pollen on the pistils of fresh normal flowers. A similar application of normal pollen to the pistils of unpollinated flowers collected at the same time and stored beside them under the same conditions shows that this aging through storage also slows down the depth of pollen-tube penetration to some extent, but the effect is much less than that produced by the previous growth of other pollen-tubes. These experiments suggest that pollen-tubes deplete the style of nutrient substance or render it slightly toxic, possibly both.

"From a series of experiments performed last year, it was definitely proved that the fertilization of ovules proceeds downward from the upper part of the ovary, that most of the seeds in the upper half of the seed capsule were fertilized by the first pollen-tubes arriving in the ovary, and most of the seeds in the lower portion of a capsule were the result of fertilization by the slower or later-arriving pollen-tubes."

Irregular Segregation in Chromosomes.

In ordinary diploid plants in the reduction division, one member of each pair of chromosomes goes to each pole, so that each daughter nucleus, and hence each gamete, gets the same number of chromosomes. In triploid plants there is a complication, either two chromosomes of each set go to one pole and one to the other, or else the third chromosome might conceivably be left in the middle and not participate in either nucleus. The former alternative is the one actually realized. The question now arises whether the cell into which the odd chromosome shall go is determined purely by chance, or whether there is any sort of attraction between chromosomes such that an excess or all of the extra chromosomes go into one of the daughter nuclei. To decide this matter, Dr. Belling has made counts on the number of chromosomes going to each pole of the spindle in pollen mother-cells, in addition to those reported previously. Over 100 double counts have been made in the regular triploid. The frequency with which each of the series of *extra* chromosome Nos. 0 to 12 occurs in this 100 agrees with the coefficients in the binomial series $(a+b)^{12}$; the middle numbers of the chromosome series are those most commonly found, but there is a slight excess over expectation of the more unequal assortments.

In haploid plants the first division has now been examined in several cases; it consists usually in a segregation of the chromosomes into 2 centers, but sometimes into 3. In the division into 2 centers the frequency of occurrence in any center of the number of chromosomes in the series 1 to 12 is, so far as observed, in close agreement with the coefficients of the binomial $(a+b)^{12}$.

Two plants from the cross of tetraploid by diploid had 35 chromosomes. These plants provided nearly 100 cases for counting the distribution of chromosomes in the dividing pollen mother-cells. The frequency with which the excess over the normal 12 at any pole was represented in the series of Nos. 0 to 11 is represented by the corresponding series of coefficients of the binomial $(a+b)^{11}$. There was a slight excess over expectation in the more unequal segregations.

One plant from the cross tetraploid by diploid had 37 chromosomes, or 24+13. Of these 13 extra chromosomes, the frequency with which the extra numbers in the series 0 to 13 went to either pole at mitosis agrees with the series of coefficients of the binomial $(a+b)^{13}$, with a slight deficit in frequency of the more unequal segregations.

These results are concerned only with total numbers of chromosomes, and do not regard the distribution of the sets of 2, 3, or 4 homologous chromosomes. It will be possible to follow the fate of such sets in the future by means of their size differences. In the cultivated hyacinth it has for some time been known (de Mol) that three size classes are easily recognized among its 8 pairs of chromosomes. These size classes have been followed in the pollen-grains of a "hexaploid" hyacinth and gave results corresponding closely with the distribution expected in each case if the chromosomes of the three different sizes assorted without mutual attraction or repulsion. *Hemerocallis fulva,* growing escaped from cultivation near the station, has been found by Dr. Belling to be a triploid; and in this case, apparently, to have the distribution of the segregation of the extra 11 chromosomes which follows the law of chance.

Non-disjunction in Tetraploid Plants.

The occurrence of non-disjunction in tetraploid plants offers an opportunity for great variation in chromosome number in the progeny. On this matter Dr. Belling reports as follows:

"The chromosome distribution has now been examined in over 100 true tetraploid *Daturas*, including special studies of 55 plants of one sibship and 17 plants of another. No plants give a constant distribution of 24+24 chromosomes. All show more or less of a segregation into 23+25, etc. The proportions in which this apparent non-disjunction takes place conform, in different individuals, more or less to the laws of random sampling varying around a mean of approximately 25 per cent of the 23+25 distribution and about 2 per cent of the 22+26. The most reliable results agree with a ratio of regular disjunction (2+2) to non-disjunction (1+3) of 35 : 1, for each quadrivalent or set of four.

"Hence a regular tetraploid, with 12 sets of 4 homologous chromosomes each, should give a certain proportion of 47 and 49 chromosome plants in its progeny. The two sibships above mentioned gave 73 plants with 48 chromosomes, 6 plants with 49 chromosomes, and 3 plants with 47. This is considerably less than the numbers of 47 and 49 chromosome plants which would be produced if all the 23 and 25 chromosome gametes were functional, and points to an abortion or failure in competition of those gametes or zygotes with excesses or deficiencies of chromosomes.

"If two gametes with 23 and 25 chromosomes, respectively, combine, the resulting 48-chromosome plant will usually have 10 sets of 4, 1 set of 3, and 1 set of 5 homologous chromosomes. Two such plants have been tested by growing their progeny. By calculation they should give 7 pollen mother-cells dividing 24+24, to 8 dividing 23+25, to 1 dividing 22+26, etc. This they did approximately, giving the proportion 6 : 9 : 1. The progeny, supposing only 24-chromosome pollen functional, and all egg-cells viable, should give plants with 46, 47, ... 50 chromosomes in the proportion 1 : 8 : 14 : 8 : 1. The proportion found was 1 : 12 : 20 : 3 : 1.

"In the progeny of such a pseudo-tetraploid, there should be some cases where two gametes meet whose sum amounts to 48, but which produce a plant having 8 sets of 4 chromosomes, 2 sets of 3 chromosomes, and 2 sets of 5 chromosomes. It may be calculated that such a plant would have a distribution of chromosomes in the pollen mother-cells of about 14 cases of 24+24, 17 of 23+25, 8 of 22+26, 1 of 21+27, etc. Two such plants have been found. In one case the chromosomes have been investigated, and 2 sets of 3 and 2 sets of 5 were found. These two plants gave the expected high ratios of the 22+26 and 21+27 distribution.

"Plants with 47 chromosomes that have originated from selfing a pure tetraploid should have usually 11 sets of 4 homologous chromosomes, and 1 set of 3. These plants should give a distribution of chromosomes, at the first division, of about 7 cases of 23+24, to 1 case of 22+25, etc. The progeny of one such plant was studied. It gave among its gametes the proportion of 7.5 cases of 23+24 to 1 case of 22+25. The progeny, if the parent's 24-chromosome pollen is solely or mainly functional, should give 1 plant with 46, 7 plants with 47, 7 plants with 48, and 1 plant with 49 chromosomes, out of 16 progeny. The actual ratio was 1 : 7 : 9 : 0.

"A plant with 50 chromosomes, in which, there was reason to think from appearance, breeding, and microscopical evidence, there were 11 sets of 4 chromosomes each and 1 set of 6 homologous chromosomes, gave the following in its selfed progeny:

Numbers of chromosomes	48	49	50	51	52
Numbers of plants	1	9	10	1	0
Calculated, 24-chromosome pollen only	3	16	3	..	..
Calculated, all pollen functional	4	4	13	0.3	0.3

"The results agree with the view that some pollen with extra chromosomes is functional here."

Diploid Plants with One Extra Chromosome.

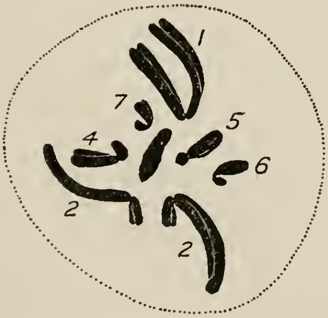
Investigation *ad hoc* is now being made of the chromosomes of the plants with 25 of them. The following methods are being used: (1) Camera drawings are made of several trivalents from each kind of plant; with a view to obtain accurate size measurements and determine the relative frequencies of different methods of combination of the 3 chromosomes; (2) camera drawings are made of complete groups of chromosomes at the first metaphase, to determine with certainty the different sizes; (3) size estimations are taken at the second metaphase, among the group of 13 chromosomes; (4) observation is made of the size of the detached chromosomes found in the 12+1+12 distributions.

Diploid Plants with One Chromosome Missing.

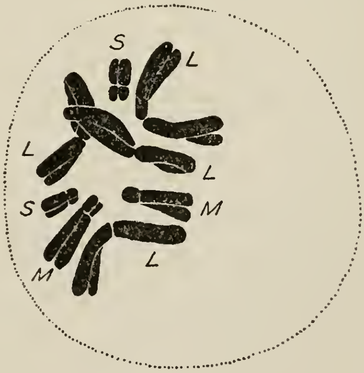
Portions of two plants and one whole plant were found by Doctors Blakeslee and Belling in this condition. Apparently in two (or in all three) of the cases it was the largest chromosome which was missing. There were 11 bivalents and 1 univalent at the late prophase and first metaphase. At the second metaphase the unpaired chromosome appeared larger than in the regular diploid.

Tetraploidy and Evolution.

If in any species the chromosome group in the soma is divisible into sets of 4 chromosomes of each size, it is probable that the species is either a tetraploid or has come from tetraploid ancestry. It has been found that often, in monocotyledons especially, an estimation of the sizes of the chromosomes is best made in the pollen-grains themselves at their first division, instead of in the pollen mother-cells or in the root tips. Plants which



1



2

Fig. 1.—Pollen-grain of *Uvularia grandiflora*, showing 7 chromosomes, of 6 different sizes.
Fig. 2.—Pollen-grain of hyacinth (Yellowhammer), showing pairs of similar chromosomes.

show two chromosomes of each size, appearing otherwise identical, in the pollen-grains (fig. 2) are probably tetraploids or descended from tetraploids. On the other hand, if all the chromosomes in the pollen-grain are of different sizes or shapes (fig. 1), the plant is not tetraploid or double diploid.

A number of species, especially monocotyledons, have been studied in this respect, such as *Cypripedium pubescens, C. acaule, Narcissus, Hyacinthus, Iris, Uvularia, Funkia,* and *Hemerocallis.* Of these, the ordinary hyacinth, styled diploid by de Mol, who counted the number of somatic chromosomes, shows in the pollen-grain (fig. 2) 2 pairs of V's, each with a clear median constriction; 1 pair of large J's, shorter than the V's; and 1 pair of short, often straight, chromosomes. The members of each pair are apparently identical. It is to be inferred that these hyacinths are either tetraploid or lately descended from tetraploids.

EVOLUTION OF THE GERM-PLASM.

Drosophila.

As pointed out in earlier reports, the genus *Drosophila,* with its numerous species, affords a unique opportunity to study the differences in the chromosomal complex of these species and to obtain the history of the changes by which these differences have been produced. Dr. C. W. Metz and associates have published (Carnegie Inst. Wash. Pub. No. 328, July 1923) a report on their genetic studies on *Drosophila virilis.* This research, of which the progress has been noted in earlier annual reports, shows that the variation from 3 to 6 pairs of chromosomes in the different species could perhaps be explained on the hypothesis that the larger number of chromosomes has been derived from the smaller by fission, or vice versa. If the 6 pairs of chromosomes of *Drosophila virilis* have been derived from the 4 of *D. melanogaster,* then the hypothesis might be tested that at least 2 of these chromosomes should be strictly homologous between the two species, and accordingly should have similar genes arranged in the same order. This hypothesis is being tested and some evidence supports it for the sex-chromosome in the two species. Here, yellow, crossveinless, singed, and forked are found in the sex-chromosome maps of the two species in about the same relation to each other. Evidence is also being obtained that minor changes, in the nature of rearrangements in the order of the genes in one small portion of a chromosome, may occur. The accumulation of evidence on these matters involves the finding of new mutant characters and the location of their genes on the chromosome map—a laborious process.

During the past year, Dr. Metz's group have found about 20 new mutant characters in *D. virilis,* making 60 in all in this species. Also, several new characters have been obtained in *D. willistoni.* Some of these new characters are of particular interest, because they appear to duplicate characters known in other species of *Drosophila.* Most of them have not been studied sufficiently to warrant conclusions at this time, but in the case of others the evidence warrants a report here. Dr. Metz reports in detail as follows:

"In *D. willistoni* the sex-linked characters scute, yellow, vermilion, and forked have already been shown to resemble characters in certain other species and to correspond to these in sequence on the chromosome map. Recently we have obtained the additional 'parallel' crossveinless, making the series *scute–yellow–crossveinless–vermilion–forked.* In *D. virilis* the series yellow, crossveinless, vermilion, and singed has been noted in previous reports. To this we have now added the parallel scute. In this case the order seems to be *yellow–scute–crossveinless–vermilion–singed.* (*Forked* in the *willistoni* series resembles *singed* in the other series.)

The sequence of yellow and scute, in relation to the other three characters, appears to be just the opposite in these two species. The relations are shown graphically in the accompanying diagrams or chromosome maps, in which are included also the X-chromosome maps of *Drosophila melanogaster* (after Bridges) and *D. obscura* (after Lancefield). Only the loci considered here are included on the maps (Fig. 3).

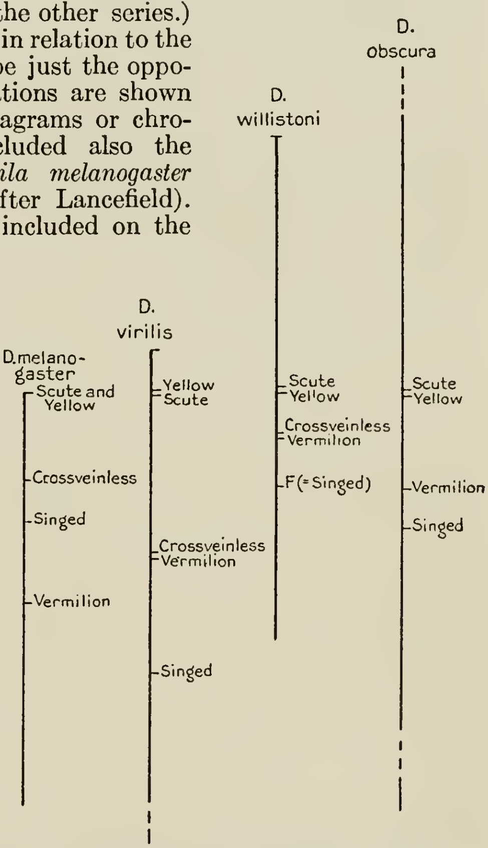


FIG. 3.—Comparison of sex chromosome. Maps in 4 species of Drosophila.

"The characters scute and yellow are emphasized because they are very closely linked in all four species. This parallelism, both in appearance and in degree of linkage of the characters, makes it seem probable that we are dealing with actual homologues. It therefore becomes of particular interest to compare their linkage relations with those of the other parallels in the species concerned.

"In *D. melanogaster* (according to Doctors Sturtevant and Bridges) scute and yellow are so closely linked that not enough crossovers have been obtained to establish their sequence; hence they are given the same locus. In *D. virilis* our evidence, just obtained, is based on experiments involving yellow, scute, and vermilion, in which three crossovers were secured, all of the same type and indicating the order given here. This number of crossovers is not large, but it is believed to be reliable in indicating the sequence.

"The two maps on the left in the accompanying figure are from species possessing rod-like X-chromosomes; the other two represent long V-shaped chromosomes. It will be noted that the sequence of scute and yellow agrees in the two species having V-shaped X-chromosomes, but is reversed in *virilis,* which has the rod-like X.

"The presence of so many 'parallels' indicated that a homology exists between the X-chromosomes of the four species, but the altered sequence suggests that a rearrangement of genes may have occurred. This is also suggested by the map position of vermilion in *D. melanogaster,* which differs from that of vermilion in the other three species. It agrees, too, with the demonstrated case of map-displacement noted by Sturtevant in the third chromosome of *D. simulans* as compared with *D. melanogaster.*

"In both *D. virilis* and *D. willistoni* the number of groups of linked genes now equals that of the haploid number of chromosomes (6 in *virilis* and 3 in *willistoni*) and the chromosome maps (based on amount of crossing over) correspond roughly to the chromosomes in size, except in the case of one map in *D. virilis*. In this species there are 5 long chromosomes and 1 very short one, and there should be a corresponding series of crossover maps; but instead the data thus far obtained give 4 long and 2 very short maps, which suggests that crossing over may be reduced in one of the 5 large chromosomes.

"One of the two linkage groups showing little or no crossing over included the characters bent and net, which resemble the characters bent and diminished in *D. melanogaster*. The latter have been shown by Bridges to be due to genes in the small chromosome of *D. melanogaster*. This suggests a homology between the small chromosomes of the two species, but we have not yet been able to make sure of the point, because, with two small linkage groups, we can not tell which represents the small chromosome. Further studies ought to settle this point soon, however.

"The character bent in *D. virilis* involves several different parts of the fly and is readily modified by environmental conditions. For this reason it has been used in an attempt to learn something of the action of the gene during development. In preliminary experiments we have been able to show that the character reacts to low temperature at a definite time, just preceding the pupation of the larva. Exposure to cold at other times has no effect. We have also found that different parts of the fly appear to differ from one another in the time at which they are affected (within the limits just mentioned), which seems to indicate that the gene acts successively in different regions, or else that it sets up reactions which give that effect."

Other Diptera.

The cytological studies on chromosome behavior, chromosome relationships, and gametogenesis, in other Diptera, particularly in the Drosophilinæ, have been continued during the year by Dr. Metz.

EXPERIMENTAL MODIFICATION OF THE GERM-PLASM.

Effect of Cold in Inducing Datura Mutants.

Since the last report, additional data have been secured on the effect of cold in inducing mutations in *Datura*. No doubt the lowered temperature induces abnormalities in the distribution of chromosomes during the formation of pollen and probably also during the formation of egg-cells. When the new constant-temperature chamber is installed it should be possible to discover with greater precision the stage at which the stimulus should be applied to bring the production of chromosomal mutations under a greater control than has hitherto been possible.

Genetics of X-rayed Mice.

This investigation, begun by Drs. C. C. Little and H. J. Bagg in 1921 is being continued by Dr. Little at the University of Maine. He reports that during the past year about 8,000 mice have been recorded. A lethal head and jaw abnormality in mice (*j*) has been found to behave as a Mendelian recessive. The eye abnormality (*h*) which occurred among the descendants of the X-rayed mice has been found to be a Mendelian recessive, overlapping normal. Abnormal feet and hair length in these X-rayed mice have proved to be hereditary, and the exact method of inheritance is being investigated.

CONTROL OF THE SEX-RATIO.

Attempts to control the sex-ratio in the little "water fleas," or Cladocera, have been continued by Dr. A. M. Banta, with the efficient collaboration of Mr. L. A. Brown, of the University of Pittsburgh. This group of organisms seems especially well fitted to throw light on the ages-old problem of how the sex of offspring is controlled, but the final solution is not yet in sight, though we are obviously approaching nearer to it.

Species Studied and Method Employed.

The main work has been done on *Moina macrocopa*. Since the beginning, three years ago, more than 800 experiments have been made with this species, and approximately 160,000 individual young have been sexed by the aid of the microscope, more than 75,000 of them this summer. Upon another species, *Simocephalus exspinosus*, a few additional experiments upon male production have been made, with very gratifying results. As pointed out in previous reports, the method of producing male offspring in these typically female-producing species is to crowd the mothers in small bottles of water.

The Critical Period of Sex Differentiation.

As a preliminary to the determination of the period at which sex of offspring is fixed, it was necessary to study the developmental cycle of the organism. Development in Cladocera does not proceed uniformly, but by a series of molts, each accompanied by a sudden increase in size. Between molts the organism is at a standstill in its size; the standstill stage is called an instar. The first brood is released at the end of the fourth instar, and a molt occurs after each brood is set free. The total number of broods may be 14 or more. The normal individuals of any instar are very similar in size and differ in size from those of any other instar. Hence the number of the instar can be determined by measuring the individual. As a result of over 1,200 measurements of lengths of females, a table of sizes for each instar has been prepared. Considering the increases in length between instars, it appears that the percentage increase in length is almost constant during the young and adolescent instars and the first two adult instars, but following this, as the animals grow older, there is a marked decrease in the percentage increase in size. These results were used also in studies on the relative metabolism of the sexes.

Experiments reported on last year indicated that sex is fixed in the ovarian egg of *Moina macrocopa* during the latter half of the instar preceding its expulsion from the ovary into the brood-chamber, i. e., in the latter half of the third instar. Additional experiments have verified the earlier conclusions and, in addition, limit the critical period during which sex of the young is subject to experimental control to approximately 4 hours previous to the passage of the egg into the brood-chamber. During this short and very definite period, sex is subject to control; following it sex is absolutely fixed.

Analysis of Sex-control Factors.

As stated in previous Year Books, the simple expedient of crowding *Moina macrocopa* and other Cladocera species causes the production of males. Most of the experiments to be reported now consisted of such crowded or semi-crowded control bottles in experiments in which the tests were modified in one way or another. Every experiment has a control and a test bottle and each control and test bottle contains equal numbers of young from the same brood and handled precisely alike, except the specific treatment given the test.

"Some of the main points of attack and accomplishment upon this problem may best be set forth by the use of a table showing some of the data. (These tabulated data are subject to subsequent verification.) The treatments may be divided into four groups: (1) aeration, to change the content of volatile substances in the culture-water or in the animals themselves; (2) change in the food directly; (3) treatment with excretory products or related substances; and (4) treatment with other substances. The aeration experiments were conducted on the supposition that the accumulation of excretory products and possibly a reduction of oxygen supply in the crowded bottles might be factors in bringing about the production of males. The aeration of the animals themselves was accomplished by exposing them to the air for a time during their 'critical period' in a thin film of water on a microscopic slide or in a Syracuse dish. Such aeration reduced but did not eliminate the production of males, inasmuch as one-third as many males were produced by the aerated mothers as by those not so treated. In other series of experiments, the test animals were reared in the same quantity of culture-water as the controls, but in a wide covered dish, so that the culture-water was only 3 mm. in depth, thus providing much greater aeration than in the control bottles. Such treated mothers produced about half as many males as the control mothers. In other large series of experiments air and, in still others, oxygen was bubbled through the test bottles. Approximately three-fifths as many males were produced in such treated bottles as in the controls. On the other hand, bubbling with nitrogen, in which case the bubbling was much less extensive, reduced the male production, but to a less extent than bubbling with air or oxygen. This suggests that scarcity of oxygen is not a factor, since the bubbling of nitrogen materially reduces the oxygen content of the treated bottles, and further suggests that, since the bubbling was less extensive and consequently removed less carbon dioxide or other volatile excretory products, volatile excretory products are factors in male production.

"Scarcity of food as a possible factor in male production is eliminated by experiments in which crowded mothers in dilute food are shown to produce only two-fifths as many males as those in the regular food solution, notwithstanding the fact that average size of the broods of young was only 9 for the dilute food and nearly 20 for the control. However, variation in the culture medium is shown to be a factor in male production, since animals reared in water containing algæ as food for the animals (instead of bacteria as in our manure culture solution) produce fewer males than those reared in the controls and fed upon bacteria (in the manure solution). Further, the age of the culture medium or of the manure used in making it up is a factor in male production, as shown by the data in line 8 of the table, the newer material producing many times more males than old material. These last experiments are of interest as accounting for the varied male percentages shown in the controls of the different series tabulated.

"Treatment with various amounts of excretory products, including ammonium hydrate, urea, urine, and chicken manure, reduced the percentage of males, though treatment with uric acid and carbon dioxide showed a somewhat greater percentage of males in the test bottles. The other agencies tabulated here (pressure excepted) reduced the percentage of males. The few experiments conducted in which the animals were subjected to pressure produced many more males in the tests than in the controls. Further tests of this are necessary, but it would seem that pressure treatment may be added to uric acid and carbon dioxide treatment as agencies increasing male production.

"In general, the experiments point to excretory products as probable causative factors in male production. Pressure may really serve merely to prevent volatilization of certain excretory products. But lacking ready means for determining the various excretory products and their relative amounts, produced in such small animals as Cladocera, it is obviously difficult to imitate and thus artificially bring about a situation duplicating that which develops in a 'crowded' bottle of these animals. Hence, if we are to formulate the hypothesis that the accumulation of excretory products is a large factor in male production, it is exceedingly difficult to bring about a treatment which will test the hypothesis. We have tested many combinations (though by no means all the possible combinations) of the presumed excretory products with only indifferent and inconclusive results so far.

Percentage of males produced in broods of Moina macrocopa subjected to various special conditions before sex is determined.

Type of special conditions.	No. of exps.	Total young sexed.	Control per cent ♂	Test per cent ♂	Difference.	Per ct. total ♂ prod. by controls.	Per cent total ♂ prod. by tests.	Effect of treatment on male production.
Changing the volatile constituents:								
1. Aeration, animals treated...........	16	4,828	55.9	19.5	36.4	74.2	25.8	Reduced.
2. Shallow dishes.....	13	2,679	38.7	24.6	14.1	61.2	38.8	Do.
3. Aeration, culture-water treated.....	21	6,108	36.6	23.8	12.8	60.6	39.4	Do.
4. Oxygen, bubbled and shaken.......	9	2,126	44.7	27.7	17.0	61.8	38.2	Do.
5. Nitrogen, bubbled and shaken.......	21	4,308	35.7	26.7	9.0	57.3	42.7	Do.
Changing the food directly:								
6. Dilute food........	2	486	40.9	25.9	15.0	61.3	38.7	Do.
7. Algal food.........	3	633	56.1	19.2	36.9	74.6	25.4	Do.
8. Old food	16	2,839	29.9	2.2	27.7	93.1	6.9	Do.
Excretory or related substances:								
9. Carbon dioxide....	29	5,487	19.4	21.9	2.5	47.0	53.0	Increased.
10. Ammonium hydrate............	19	4,283	34.6	17.5	17.1	66.5	33.5	Reduced.
11. Uric acid.........	19	4,091	10.1	11.4	1.3	47.0	53.0	Increased.
12. Urea.............	35	6,131	6.9	4.7	2.2	59.5	40.5	Reduced.
13. Urine............	41	8,552	19.1	7.2	11.9	72.7	27.3	Do.
14. Chicken manure..	8	1,570	11.6	2.2	9.4	84.1	15.9	Do.
Other agencies:								
15. Sodium hydrate ..	8	1,026	12.4	11.1	1.3	52.3	47.7	Do.
16. Sulphuric acid....	21	3,530	10.5	7.0	3.5	60.0	40.0	Do.
17. Alcohol..........	10	2,247	37.2	0.2	37.0	98.5	1.5	Do.
18. Pressure.........	4	669	2.4	12.6	10.2	16.0	84.0	Increased.
19. Dried daphnids...	5	1,053	8.5	2.2	6.3	79.5	20.5	Reduced.

"The conclusion would seem to be that the conditions favoring male production are quite complicated, that excretory products probably constitute a large factor, that there is a delicate balance which, if much disturbed, as by most of our treatments, results in a reduction in male production, but that any treatment which materially affects male production throws light on the situation involved and promotes the analysis correspondingly.

"To summarize the treatments catalogued in the table, aeration by whatever method, changes of whatever nature in the food, treatment with many excretory products or related substances—ammonium hydrate, urea, urine, chicken manure, and treatment with alcohol, sulphuric acid, and sodium hydrate—have resulted in reduced male production. On the other hand, animals treated with carbon dioxide, or uric acid, or reared under pressure, have produced increased percentages of males."

Control of Production and Hatching of Sexual Eggs.

Previous knowledge of production of sexual eggs in Cladocera (in which only parthenogenetic eggs are ordinarily produced) has been extended. Control measures are somewhat difficult, but means of an entirely practicable sort have been developed for *Moina macrocopa* and *Daphnia longispina* and one of our types of *Daphnia pulex*. There is reason to think that these measures may be readily modified so as to apply to most, if not all, the other Cladocera under cultivation. Hatching the fertilized sexual eggs is more difficult than their production, but those of two of our forms may now readily be hatched and some of those of *Daphnia longispina* have been successfully hatched into viable offspring. The occurrence of sex intergrades in two of our laboratory stocks and of two other clear-cut mutations in *Daphnia longispina* makes hybrid matings a matter of much interest. Our attempts at hybridization have so far been unsuccessful, but will be continued.

Cytological Work on Cladocera.

The occurrence of sex intergrades in two species of our Cladocera stocks, and the ability to control through environmental conditions the sex of Cladocera, make the chromosome situation in these animals a matter of much theoretical interest. Cytologically, Cladocera are very difficult, and the services of a good cytologist seemed essential in attacking this problem. Dr. Ezra Allen, of Ursinus College, whose improvements in cytological technique have made accurate studies in mammalian cytology possible, spent two months with us this summer and made a good start upon the study of the cytology of two species of Cladocera. He reports as follows:

"Fixation was made in Fleming's fluid, 10 per cent formalin, Dantchakov's, and B-15 (Allen's modification of Bouin). Fleming proved of no value for the large eggs; its effect upon the chromosomes in the younger tissues has not yet been studied. The fixation of the testis proved quite satisfactory in B–15.

"As to stages studied, since the chief interest in this form lies in the sex differentiation by the parthenogenetic female, the period of, and immediately following, egg-laying was studied at first in hope of determining the maturation phenomena. The large quantity in the yolk of coloring matter that takes both hematoxylin and safranin made this an undesirable and difficult stage to do the first work upon. Consequently embryonic and post-embryonic stages were studied, in females only at first. These consisted of embryos fixed at 13.5, 16, and 20 hours after egg-laying, and of young about ready to be released from the brood-pouch. The young were fixed at about 2, 8, 16, 18, 24 to 26, and 36 hours after release from the brood-pouch. Young males were fixed at 15, 18, 24, 12 to 36, 30, 24, 48, 60, and 72 hours after release.

"The results were that no dividing oogonia were found. Cell division was active in the testes of the 24 and 60 hour stages. The older males have not yet been studied. The cells are very small and not favorable to study. Apparently the haploid number is in the neighborhood of 8 chromosomes, agreeing with Kühn's estimate of *Daphnia pulex*. The material, while difficult of observation, appears capable of count determination in both spermatocytes and spermatogonia.

"The dividing cells in embryonic tissue are exceedingly small, and it may be impossible to determine the number in the ordinary cells. The oogonia are readily differentiated in embryos 16 hours after discharge from the brood-pouch, and under favorable conditions their chromosomes should be readily studied. The number of oogonia laid down at the 16-hour stage is about 14 to 16. This number more than doubles by the time the embryos are ready to be released. While no counts have been made of the number of oogonia and eggs when the growth stages of the eggs have begun, there seems to be a considerable increase over that of the stage when ready to be released.

"On account of the inherent difficulties in the material of *Daphnia longispina,* it seemed best to work out the cytology of *Moina* before continuing the studies of *Daphnia longispina.* In *Moina* the sex-ratio is influenced by crowding mothers in bottles, much as in *D. longispina.* There is much less yolk and practically no coloring matter in the eggs, conditions which favor the study of maturation stages."

COMPARISON OF METABOLISM IN THE SEXES.

In past years this Department has contributed to the knowledge of the relative metabolism in the production of male and female eggs of pigeons. The existence not merely of males and females, but also sex intergrades in Cladocera, added interest to an investigation of the metabolism of the sexes in this group of aquatic organisms. Dr. V. Obreshkove, of Syracuse University, spent the summer at Cold Spring Harbor determining the rate of carbon-dioxide production in some of Dr. Banta's stock. The rate of carbon-dioxide production serves as an index of the rate of respiration and metabolism in general—the life processes of the organism. To measure the amount of carbon dioxide produced in a given time, a modified Osterhout apparatus was used. Dr. Obreshkove reports as follows:

"The principle involved in the simple apparatus is the colorimetric method of hydrogen-ion determination. Carbon dioxide affects hydrogen-ion concentration. A measure of the time required for the animals to change a constant quantity of indicator solution from one standard hydrogen-ion concentration to a second standard hydrogen-ion concentration is a measure of their rate of carbon-dioxide production. Animals to be tested are placed in a closed tube the color of which accurately matches that of a similar tube which is a standard, containing buffer solution of the same hydrogen-ion concentration, 7.76, and containing the same indicator. The tubes are then gently shaken by tipping them by an apparatus driven by an electric motor. When the color in the tube containing the animals is changed by these animals so that this tube matches in color a third tube containing indicator and buffer solution of a hydrogen-ion concentration of 7.36, the time is recorded (by means of a stop-watch). Successive readings of different animals (and on different days and by different observers) of the same developmental stage are remarkably consistent. With this apparatus a fine series of determinations was obtained for (1) four stages in the developmental cycle of normal *Simocephalus exspinosus* females, (2) mature males of the same species, and (3) mature females of *Moina macrocopa.*

"The very small young just released from their mother's brood-chamber were tested 10 at a time, the time required to produce the standard color averaging 93 minutes and 46 seconds for 10 individuals. Hence for one individual the mean reaction-time is 937 minutes. For mothers which had just released their first brood the mean for one individual is 9 minutes 51 seconds. Other data are given in the table. The first-brood mother is approximately 44 times as large in actual bulk as a newly released young. Hence, if the rate of carbon-dioxide production were the same, size considered, in young and first-brood mothers, the first-brood mothers should have a reaction time one forty-fourth that for the young, or 21 minutes 19 seconds. Since the actual mean for first-brood mothers is 9 minutes 57 seconds, it is evident that the rate of respiration, and hence the metabolic rate, is greater, size considered, for first-brood mothers than for young females. In fact, it is 219 per cent greater. For fifth-brood mothers (see table), 84 times as large as the young, the rate is 149 per cent that for the young. For ninth-brood mothers, approximately 121 times the bulk of the young, the rate is 66 per cent that of the young. The table gives figures for these comparisons.

Data on the rate of carbon-dioxide production in developmental stages of Simocephalus exspinosus.

	Average length of individuals tested in millimeters.	Approximate number of times the individual surpasses the young in size.	Mean reaction time per individual in seconds.	Rate of carbon-dioxide production, size considered, compared with young (per cent).
Newly released young.....	0.63	....	56,263	....
First-brood mothers.......	2.23	44.4	591	219
Fifth-brood mothers.......	2.76	84.2	457	149
Ninth-brood mothers......	3.12	120.7	711	66
Mature males............	1.09	5.2	4,589	243

"These data indicate that metabolic rate is relatively high in the first-brood mothers, decreases in the fifth-brood mothers, and shows a still greater decrease in the already senescent ninth-brood mothers. The mature males may be fairly compared with the first-brood mothers. Their rate is, bulk considered, approximately 111 per cent that for the females at the same stage of development. The data are consistent with data of other workers for higher (and much larger) animals, including man, in which the metabolic rate decreases later in life in both sexes and is higher for the male. This first attempt to obtain a measure of metabolic rate in Cladocera opens up a large field, and it is hoped will be extended and continued to the sex-intergrade stock and to several other Cladocera problems."

SELECTION WITH SEX-INTERGRADE STRAIN OF DAPHNIA LONGISPINA.

Experiments on the effect of selection upon the degree of sex intergradeness in various strains of *Daphnia longispina* (referred to in previous Year Books) have been completed. Sex intergradeness appears due to a factor (or factors) which is subject to genetic changes, so that selection and return selection are effective, success depending of course upon our utilizing mutants in our selections. Intergrade production in the lines selected toward reduction of the character has in some cases become restricted to the scanty production of slightly intergrade individuals, and in one line no intergrades of any sort have appeared for eight successive generations. On the other hand, the high trains produce mostly intergrades of fairly high rank.

Selection with Sex-Intergrades of Simocephalus exspinosus.

An effect of "selection" in modifying the sex-intergrade stock of *Simocephalus exspinosus* was not obtained for a time, but has subsequently been realized to a gratifying degree. Of the two "low" lines, one has produced only normal females for the last 8 successive generations, i. e., selection has apparently eliminated the production of intergrades. The other low line has produced no intergrades for the last 23 successive generations. On the other hand, the two "high" lines continue to maintain their usual production of intergrades.

Sex in Relation to Metabolism in Pigeons.

During the year Dr. Riddle has completed some studies on certain aspects of sex and on the relation of "reproduction overwork" to sex in pigeons. Most of these current studies have also been prepared for early publication in various journals. Other results are being incorporated into a complete account of his sex studies.

Determination of Sex in Date-Palm Seedlings.

During the past year considerable progress has been made in the date-palm problem, the most important element of which has been the determination of the chromosome number. The problem was formulated and the material collected by Dr. H. H. Laughlin, the cytological work done by Misses Elizabeth Lord and Rachel Haynes. The haploid count has given 18 chromosomes. Material taken from plants, the sex of which is definitely known, is being prepared for comparative studies in an effort to make an early diagnosis of sex. Practically, the sex of seedling date-palms can not be determined until the plant blooms at the age of 3 or 4 years. The purpose of these studies is to seek a sex-diagnosis in the sprouting seedling, without destroying the seedling itself.

GERMINAL AND SOMATIC VARIATIONS.

Mutations and their Selection in Cladocera.

Sex intergrades occur abundantly in certain lines of *Daphnia longispina*, and the effectiveness of experiments on selection proves that mutations frequently occur in sex-intergrade stock. One of the other mutant stocks, the "excavated head" stock, has been similarly subjected to selection as a method of analyzing the constancy or mutability of this character. Of six strains (derived from sisters and at the start producing the mutant character to an equal extent), three were taken for "high" strains and three for "low" strains. Selection has proceeded for 65 generations. Of the low strains, one showed in the second generation a lowering of the curve of "degree of excavation," and the drop increased materially after the fifty-ninth generation. Its present average grade of manifestation of the character is approximately one-eighth of its original average. Another low strain showed an effect of selection after 10 generations and a further drop after 19 generations of selection. It now averages about one-fourth of its original average manifestation. The third low strain showed no decided decrease in manifestation of the character until after the fifty-fourth generation of selection, and has shown no further drop. It now averages approximately one-sixth of the original manifestation. Of the three high strains, two have shown no decided increase in the manifestation of the character. The other showed slight increase after 7 generations and a marked increase after 12 generations of selection. It now averages about double its original manifestation of the character, an average approximately 15 times as great as the present average for the low strains. The appearance of the polygons showing the course of this selection experiment suggests that changes in manifestation of the character are of the nature of mutations of smaller or larger degree.

The studies in selection with Cladocera, the first of which was published by the Institution (Carnegie Inst. Wash. Pub. No. 305), demonstrate that in these parthenogenetic organisms genetic changes of the nature of mutations may occur with relative frequency and, as regards a particular character, with probably as great frequency as in most organisms reproducing bisexually.

INHERITANCE OF SPECIAL TRAITS.

Flowering Plants.

The physico-chemical properties of the leaf-tissue fluids of Egyptian and Upland cotton and of their hybrids.—Investigations have been continued by Dr. J. A. Harris and his collaborators along the lines discussed in earlier reports. A comparison of Pima Egyptian and Meade and Acala Upland cotton and the F_1 hybrid has been completed for publication. A study of several newly-imported Egyptian types with respect to osmotic concentration, specific electrical conductivity, hydrogen-ion concentration, and chloride content has been begun.

As at present conducted, these studies involve not merely the comparison of genetically distinct types, but an investigation of the differences in their relationship to the substratum. In addition to the Egyptian cottons, Sea Island has been included in the work carried out in 1923, and some observations made on variant types of both Egyptian and Upland cotton. From the standpoint of methods, the most important advance has been the addition of the determination of the sulphate ion, improvements in the method of determining the chlorine ion, and the rapid determination of reducing sugars. These determinations make possible a more analytical consideration of the variables to which osmotic concentration and electrical conductivity are due.

The studies made in 1923 were limited to the Gila River Indian Reservation, where facilities were afforded by the Cooperative Testing Station. In this work Dr. Harris was assisted by Professor John V. Lawrence, Dr. G. O. Burr, Mrs. John V. Lawrence, Mr. W. B. Sinclair, and Mr. Charles W. Crane. The work in 1923 was mainly devoted to Pima Egyptian and Lone Star Upland cotton and their F_1 hybrids. Preparations for the investigation of the F_2 hybrid are under way.

Genetical analysis of white seedlings of maize.—Dr. M. Demerec is continuing here, in cooperation with Professor R. A. Emerson, of Cornell University, certain experiments on the genetical analysis of white seedlings in maize which he began while in Ithaca, New York.

Variation and Correlation of Fecundity in the Domestic Fowl.

These studies have gone forward steadily during the year, under th direction of Dr. J. A. Harris. Further reports are in press, and considerabe progress has been made towards completing a volume summarizing the results of all the work.

HEREDITY OF LEARNING CAPACITY IN MICE.

Miss E. Vicari was a guest of the Department during the summer and continued her investigation into the rate of learning a maze shown by mice of distinct races and hybrids between them, reported upon last year. She has bred the F_1 and F_2 generations of the hybrids between X-rayed mice and the dilute brown race which have been bred in this Department and which show different reaction times.

SUSCEPTIBILITY TO INOCULABLE TUMORS.

The experiments on the genetical factors responsible for susceptibility to inoculable tumors, described in earlier Year Books (1921, pp. 122–127; 1922, pp. 113–114), have been carried out by Dr. L. C. Strong, partly in association with this Department, partly with the aid of a grant from the Rockefeller Institute for Medical Research. Last year was reported the discovery of a tumor dbrB, susceptibility to which depended, apparently, upon the presence of at least two independent factors, since a typical 9: 7 ratio was obtained in the F_2 generation produced from a cross between a susceptible (dilute[2] brown) and a non-susceptible (Bagg albino) strain of mice. Dr. Strong has isolated several genetic families from the F_2 generation and continued them by brother-sister matings to the F_6 generation. One of these families (known as the E VII) has been selected for high percentage of susceptible individuals. In the F_4 generation of this family the following result was obtained: Adding together all of the F_4 progeny derived from E VII, F_3 matings, in which both susceptible and non-susceptible occurred in the individual matings, the ratio of 94 susceptible to 38 non-susceptible individuals is obtained. This ratio is probably a Mendelian 3: 1 ratio, for an ideal 3: 1 ratio would give 99 susceptible to 33 non-susceptible. This result indicates that the F_3 parents differed in only one Mendelian factor. Thus Dr. Strong seems to have achieved the long-looked for result of isolating a family in which the difference between susceptible and non-susceptible individuals depends upon only a single gene. The gene has been called the A^{st} factor. It was already shown (Year Book 1922, p. 113) that the dbrB strain carried two demonstrable factors, A^{st} and B^{st}. The genetic constitution of individuals of the E VII family, as far as their reaction to the dbrB tumor is concerned, is as follows: Non-susceptible individuals have the genetic constitution $a^{st}\ a^{st}\ B^{st}\ B^{st}+$; susceptible individuals have the genetic constitution $A^{st}\ a^{st}\ B^{st}\ B^{st}+$, or $A^{st}\ A^{st}\ B^{st}\ B^{st}+$, the difference being the single factor A^{st}. This family E VII has been continued to the F_6 generation.

Dr. Strong has also made an analysis of the rate of growth of tumors and has demonstrated several important facts which indicate that the difference between two individuals in the growth-rate of the transplanted tumor is caused by genetic differences. Only a part of the evidence may here be cited:

> "(1) Within limits, the growth of the individual tumor is constant. By plotting the logarithms of the observed mass of the tumor at uniform lengths of time after inoculation there is obtained a straight line. When the growth rate is slow, the straight line is evident for 7 or 8 weeks after inoculation, whereas when the growth is rapid, the straight line is evident for only about 4 to 6 weeks (fig. 4).
>
> "(2) Individuals belonging to the different hybrid generations grow the same dbrB tumor at significantly different rates. For instance, an indi-

vidual of the homozygous dilute-brown (susceptible) race grows the tumor very slowly. An F_1 hybrid individual (produced by crossing the dilute-browns to the Bagg albinos) grows the same tumor (dbrB) much faster. By continued back-crossing to the original dilute-brown race, the various back-cross individuals grow the same tumor progressively slower and slower until in the advanced back-cross generations only individuals that grow the tumor at the same slow rate as the original dilute-brown individuals are obtained.

"(3) The range of variability for the absolute mass of the tumor at any given interval after inoculation is greater in the F_2 and F_3 generations than it is in the original susceptible dilute-brown strain as well as the F_1 hybrid generation. It is apparent, therefore, that multiple genetic factors are concerned in the growth of the transplantable tumor.

"(4) Families containing individuals growing the same transplantable tumor (dbrB) at different average growth rates can be isolated and continued by selected matings. Figure 4 contains three families, all individuals belonging, however, to the F_4 generation. These families were separated from the F_2 generation and kept distinct up to the present time. Brother-to-sister matings have been used exclusively."

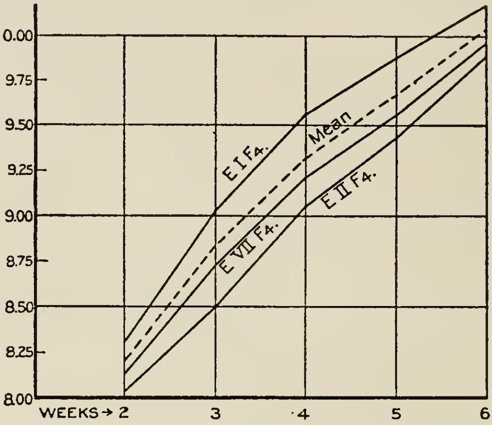


FIG. 4.—Curves of average weight development of tumor in each of three families. Ordinates, logarithm of weight in grams.

In the lines of the dBrA and dBrB, which Dr. Little is continuing at Orono, Maine, five spontaneous tumors have arisen in closely related individuals. One of these is being investigated genetically by Miss B. W. Johnson, who has inoculated over 150 mice of F_1, F_2, and back-cross generations. Miss E. E. Jones also is engaged in isolating new single-factor lines for these tumors, by methods so successfully used by Dr. Strong.

SUSCEPTIBILITY TO ALCOHOLIC INTOXICATION.

The idea is commonly held that certain groups of men are especially immune to alcoholic intoxication; but whether this immunity is due to individual accommodation or is a consequence of a selective process extending through generations is not known. During the progress of the alcoholization of white rats it was found that certain ones always required more than others to yield complete intoxication, but no special records were made of such facts. To attempt to analyze genetically such a subtle character as the susceptibility to alcoholic intoxication might seem too difficult were it not for the successful work of Little and Strong in studying the genetic basis of an even more subtle character, namely, susceptibility to implanted tumors. A series of experiments directed toward the formulation of criteria for comparing the behavior of mice under alcoholic anesthesia has been completed and certain preliminary results have been obtained by Dr. E. C. MacDowell. Over 100 mice have been used in these experiments; of these, 60 have been tested daily for one to four months. The detailed account of methods may be deferred to the final report. Dr. MacDowell reports as follows:

"The most important result so far obtained from the dose of 3 c.c. for 45 minutes is that the criteria used bring out characteristically different behavior in different mice. Some mice, week after week, give the same reactions; many will regularly turn over at once on coming out of the anesthetizing bottle, run along, and hold back from the edge of the table; others, quite as regularly, will turn over and run along, but fall off the edge three times in succession; again, a mouse will always sit still for a while after turning over at once, and others will lie on their sides for an hour or two before turning over at all. Besides these cases of uniform behavior, all degrees of variable behavior are found, but in the latter cases as well individual characteristics are evident; a mouse will usually turn right over, but every four or five days it will lie on its side for a while; another will never lie on its side, but will usually fall off the edge, with once in a while a day of holding back from the edge. A curious type of incidental behavior is shown by members of one litter, which, after partial recovery, frequently raise their heads, pointing their noses straight up in the air, and then slowly wave one front paw up and down. Nothing approaching this behavior has been seen outside this litter.

"When the mice are left in their bottles every day until they are drunk, the criteria of comparison become reduced to the time necessary to produce motionlessness and the time for recovery. Records have been taken from 22 mice so treated. By this treatment the individual differences are less strikingly brought out, although certain ones clearly take more time to become drunk and others as clearly take more time to regain control.

"The existence of individual differences opens the way for the discovery of strain differences. Although the experiments thus far carried out have been primarily devoted to the study of methods, one case may be cited which suggests that a genetic difference may be involved. From two different lines two litters, of 5 and 6 mice, respectively, all of the same age, were started on the same day with the 45-minute alcohol treatment, and thereafter they were dosed simultaneously. All the males lived in one box and the females in another. Both males and females of one litter regularly turned over, ran along, and held back from the edge of the table, while all of the other litter either lay on their sides, sat still, or fell off the edge.

"Of interest is the rapid accommodation made by the majority of mice to the light dose. They generally lay on their sides after the first treatment at a month old; the time varied from 30 minutes to 2 hours. After 5 or 6 days the mice would usually turn over at once and go away. There is little evidence of further accommodation after the first week, even though the treatment be continued for 4 months. These specially susceptible ones that continue to lie on their sides throughout the treatments do not show a gradual shortening of the time spent on their sides. In the case of the heavy treatment there is an initial period of lengthening treatments, which soon ends, and in some cases the period of treatment then remains fairly constant, while in others it declines. Where there is a decline it is evident that the mouse is losing rather than gaining resistance.

"The effects of temperature on alcoholization and recovery are being studied; but so far are not found to be marked."

NEW MOUSE MUTATIONS.

Both at Cold Spring Harbor and at Orono, Maine, eye abnormalities have been discovered in non x-rayed lines. The Orono mutant, discovered by

Miss E. E. Jones, arose in the Bagg albino races. A white ventral patch mutation was discovered by Miss Johnson and is being genetically investigated by her. It appears to be a recessive. A mutation involving a white tip or band on the tail is also being investigated and its relation to the ventral patch is being considered.

Heredity in Sheep.

The experiments on heredity of twinning in sheep were continued during 1922 and 1923, using as ram, in place of the member of a triplet set, a new ram, the only lamb borne by his mother in 1920. In 1922, 11 lambs were born—3 pairs of twins and 5 as single births—or an average of 1.38 per fertile ewe. In 1923, 28 lambs were born, from the same sire, an average of 1.75 lambs per fertile ewe. Thus using the same sire the proportion of multiple births was greatly increased in the second year. This result can not be ascribed to the greater fecundity of new ewes bred from in the second year; it indicates rather improved vigor of the ram in his second year (a fairly obvious fact to the casual observer). The return to a fairly high fecundity, with nearly the same stock, in the second as contrasted with the first year, shows the importance for multiple births of a vigorous male.

Genetics of the Thoroughbred Horse.

At the request and expense of Mr. Walter J. Salmon, of New York City, Dr. Laughlin has organized studies which have for their purpose the coordination of the performance and pedigree records of the Thoroughbred horse, and the current breeding practices, by the aid of modern genetical knowledge and methods of analysis. A library of very rare and valuable early pedigree and performance records, purchased by Mr. Salmon, is used for this study. There is perhaps no other collection of pedigree records extant for any plant or animal which gives so complete and satisfactory performance data as the speed-records of the Thoroughbred horse. This fact makes the work particularly promising, both for the elucidation of the practical breeding principles of this particular breed of horse, and also (using the methods of pedigree analysis) for the prediction of performance in offspring. The detailed statistical work is being done by Messrs. Clyde E. Keeler, Pierre Hernandez, and Misses Luella A. Smith and Alice Hellmer.

As one of these special studies in horse genetics, Dr. Theophilus S. Painter, of the University of Texas, made investigations at Cold Spring Harbor during the summer of 1923, which resulted in a satisfactory and conclusive count of the chromosome number in the horse. The diploid number is demonstrated to be about 60, including a clean-cut X Y type of sex-chromosome.

Rabbits.

Professor H. D. Fish, of the University of Pittsburgh, as associate of this Department, has continued his researches on the extremely valuable strains of rabbits which he is breeding. The maintenance of these strains encounters certain difficulties arising from parasites, which at times have killed 95 per cent of the offspring. Professor Fish has devised and installed partially self-cleaning cages, and the mortality is now much reduced.

New and improved grading scales have been introduced both for Dutch and English rabbits, to indicate quantitatively the proportion of white pelage in these piebald races. The lines of self, tan Dutch, white Dutch, dark Dutch, and others are being continued, although high mortality has threatened some of them. Professor Fish reports that he now has two different stocks, each carrying 5 or more recessive factors, and, between them, all of the recessive factors that have been carefully worked out in rabbits are represented. An attempt has been made to repeat Professor Guyer's experiments on the effect of specific sera upon the germ-plasm, but no positive results have been so far gained.

STUDIES ON HUMAN GENETICS.

Heredity in Aristogenic Families.

Dr. H. J. Banker has continued his compilation of the genealogy of a New England family from the eugenical standpoint, following the plan of his paper entitled "The ideal family history," presented before the International Congress of Eugenics. The selected family is one which has shown considerable incidence of eminent scholarship. The plan involves the study of the propositus, his consort, and their ancestry for three generations; also each of their posterity, with the ancestry of each consort. The total number of descendants issued from the propositus is now 235, of whom 63 have had issue. The completed manuscript would include several thousand typewritten pages.

Dr. Banker has continued his collection of scholarship records of coeducational schools, with the aim of studying inheritance of special scholarship. Fortunately he has found, in the adjacent village of Huntington, high school records dating from 1859. They are well preserved and complete from the time of its foundation, and contain a number of instances of not only children but also grandchildren of the earliest students. On account of the stable character of its population and the prevalence of local intermarriage, there appears to be an unusual number of instances of children and both parents educated in the school. Dr. Banker believes the material to be the most valuable in quantity, if not in quality, of any that has yet been obtained.

Heredity in Cacogenic Families.

Dr. A. H. Estabrook has completed his report on the Tribe of Ishmael and submitted it for publication. All original data on the tribe have been filed in the archives of the Eugenics Record Office. Also, there was deposited in the archives a duplicate copy of all data gathered by the Indiana Committee on Mental Defectives during the years 1916 to 1923. This includes some family histories and surveys of mental ability.

Since the middle of November 1922, Dr. Estabrook's time has been chiefly spent in the field on the problem of the South Appalachian population. In seeking to find the best place in which to start, he had conferences at social agencies in New York City, made a tour of the Appalachians through the Virginias, Carolinas, and eastern Kentucky and Tennessee. On this trip men and women who had information about the population of the mountains were visited and consulted as to the proper locations for the first field work. Particularly valuable contacts were made at Berea College, Lincoln Memorial University, University of Tennessee, Asheville Normal School, University of North Carolina, State Board of Public Welfare, Raleigh, North Carolina, and University of South Carolina. Opportunity was gained to learn of movements of the population to cotton mills and coal-mining fields, and conferences were held with mill superintendents as to source of supply of their workers. The need for certain special studies was urged, such as the Indian-negro-white crosses in the Blue Ridge of Virginia and the Croatans of the coast of the Carolinas.

The first field work was carried out with an Indian-negro-white cross in Amherst County, Virginia, in collaboration with the Department of Sociology of Sweet Briar College, whose students carried on field work under the immediate supervision of Professor I. E. McDougle. About 500 members of this Amherst group have been located and more or less studied.

The major field operation was started in February 1923, in the mountains of eastern Kentucky, in Leslie County, and is being continued. This area was selected because of its inaccessibility; no railroads enter the county and no industrial development has taken place in it. The county is without improved roads, so that all travel is on horse or mule back, mainly in creek beds. A saddle horse has been purchased by the Department for use of Dr. Estabrook. There are about 25 main families in the county, nearly all dating back to 1800 and coming of hunting stock. Much intermarriage has occurred, little immigration since 1800, but considerable emigration in consequence of the Civil War and the call of the coal mines. A study is being made of these old families.

'HEREDITY OF BODY-BUILD.

The Director's paper on this subject is being printed by the Institution. In it two types of variation in build are distinguished, the ontogenetic and the adult. The ratio of chest-girth to stature is regarded as the best index of build; and, where chest-girth is unknown, for adults, weight÷stature^2. Racial, geographical, and ontogenetic differences in build are discussed. Changes in adult build with age are relatively greater in families characterized by obesity. The mass polygon of distribution of build shows two modes at all ages, evidence of at least two biotypes of build. Slenderness is associated with tendency toward tuberculosis, pneumonia, nervousness, melancholia. Slender parents have smaller families than fleshy ones, and their children show less regression toward mediocrity than those of fleshy parents, and they are less variable, suggesting that there are recessive genes for slenderness carried by the fleshy. There is a marked tendency for persons of similar build to intermarry. Not all persons of the same build are gametically alike. Some slender parents carry 1, others 2, zygotic factors for build. Some parents of medium build are heterozygotes; others belong to a medium-build biotype. The F_1 generation derived from a slender×fleshy mating is quite variable, as is commonly found where multiple factors are concerned. Its mode is fleshy, indicating partial dominance of that condition. The F_2 generation is still more variable than the F_1. The back-cross of a heterozygous parent with either parental type tends to fall into heterozygous build and the build of the particular parental type to which the back-cross is made.

It is considered that variations in build are not to be accounted for merely by variations in the relation of intake and outgo of calories, but also by the endogenous factors that determine "economy of nutrition" or the cost in energy of adding an additional kilogram of weight to the body. Hereditary factors are involved in producing such differences and probably work through the intermediacy of special organs that influence metabolism, notably the endocrine glands. In some cases, at least, three independent factors are involved in very fleshy build, but the number is not the same in all biotypes; in some there is only one, in others 4 or more.

Further collections of family data on body-build are being made by Miss Louise A. Nelson under the Lawrence Memorial Research fund of the Playground Athletic League, of which Mr. Robert Garrett is president and Dr. William Burdick is director.

Heredity of Radio-Ulnar Synostosis.

In cooperation with Dr. Henry Ling Taylor, the New York pædiatrician, a study was made on the heredity of a relatively rare condition by which radius and ulna are congenitally fused at their proximal end. With the assistance of Miss Louise A. Nelson, who did the field work, 15 families were studied; 23 new cases are listed and described; they fall into two types. A review of the mammals shows that proximal radio-ulnar synostosis is not rare. In man the condition is often associated with other bony defects. In most families the inheritance is that of a 2-gene trait, in others of a 3-gene trait. In one family the single gene appears to be in the Y-chromosome. Always synostosis is dominant. Males are twice as apt to be affected as females, taking all families together. Consanguineous matings are frequent in synostotic families. A review of the literature as compiled by Miss Mabel L. Earle accompanies the paper.

Correlation Between Physical and Mental Development in Man.

At intervals, further measurements of idiot boys have been made by the Director at Letchworth Village, with the kind cooperation of Dr. Charles S. Little, superintendent. One paper by Dr. Bertha E. Martin and myself, embodying the earlier studies, is in press, and further analyses of the data were made by Dr. Martin in the summer of 1923. Miss Louise A. Nelson made field studies in central New York State upon the families of these boys.

Variation, Correlation, and Racial Differentiation in the New-Born Infant.

The statistical investigation of the data for new-born infants, abstracted from the records of the Sloane Hospital for Women, New York City, has been continued by Dr. Harris.

GENETIC CONSTITUTION OF THE AMERICAN POPULATION.

Eugenical Sterilization.

In December 1922 the volume on "Eugenical Sterilization in the United States," prepared by Dr. H. H. Laughlin, was published by the Municipal Court of Chicago. Chapter headings are as follows:

Chapter I. Chronological list of laws, amendments, executive vetoes, repeals, official legal opinions, board orders, and court decisions relating to eugenical sterilization previous to January 1, 1922.
Chapter II. Analysis, by States, of sterilization laws enacted prior to January 1, 1922.
Chapter III. Texts and legislative records of the eugenical sterilization laws.
Chapter IV. Statistical and descriptive summary of eugenical sterilization in the several States.
Chapter V. Analysis of the eugenical sterilization laws by subject.
Chapter VI. Analytical outline of litigation growing out of the several eugenical sterilization statutes previous to January 1, 1922.
Chapter VII. Detailed review of litigation growing out of the several eugenical sterilization statutes.

Chapter VIII. Case and family histories of individual subjects of litigation growing out of the several eugenical sterilization laws.
Chapter IX. Legal opinion.
Chapter X. The right of the State to limit human reproduction in the interests of race betterment.
Chapter XI. Eugenical diagnosis.
Chapter XII. The anatomical and surgical aspects of eugenical sterilization.
Chapter XIII. The physiological and mental effects of sexual sterilization.
Chapter XIV. The legal, biological, and practical requirements for an effective eugenica sterilization law.
Chapter XV. Model eugenical sterilization law.
Chapter XVI. Explanatory comments on the model sterilization law.
Chapter XVII. Set of forms suggested for the use of the State eugenicist, the courts, private citizens, and custodial institutions in administering the model eugenical sterilization law.

An attempt was made to make a thorough historical, legal, and statistical review and analysis of the subject in order to determine, from first-hand knowledge, the practice and tendency in eugenical sterilization, to examine these practices in the light of constitutional law, biological principles, and eugenical practice. The principal scientific results of the investigation are summarized in Chapter XV, entitled "Model eugenical sterilization law," in which, according to the opinions of the jurists who have examined the work, the legal requirements of an effective sterilization law have been met. Similarly, analyses of State practices in complying with the several laws were used in developing and incorporating in the law the essential biological and eugenical requirements.

In analyzing the matter of physiological and mental effects of eugenical sterilization (Chapter XV), records of 694 cases of sexual sterilization were studied. Analyses of these cases show that vasectomy in the male and salpingectomy in the female, when performed by skilled surgeons, exercise little or no influence either upon secondary sexual traits or upon the sexual impulse; nor could any severe mental or temperamental effects, especially among the socially inadequate classes, be found which logically could be ascribed to sexual sterilization, by either of the two methods just named.

From the purely eugenical point of view, the analysis was based upon actual pedigree records of families of social inadequates. From this analysis it was concluded that—

> "With due heed to the legal, biological, and practical considerations . . . . there is every reason to believe that the greatest benefit would accrue to the natural hereditary qualities of future generations from a law providing for the eugenical sterilization of certain hereditary degenerates and defectives" (p. 444).

The analysis of the legal situation justifies the following conclusion:

"A State may, in the proper and constitutional exercise of its police power, enact practical and enforceable eugenical sterilization laws, devoid of punitive features, but which may include criminals, and which have for their sole purpose the improvement of the natural hereditary physical, mental, and moral endowment of future generations: *Provided*, (a) that such laws are not so unduly discriminatory in their application as to constitute the denial of equal protection of the laws guaranteed by Section 1, Article XIV, of the Constitution of the United States, to all of the citizens of all the States, and (*b*) that such statutes provide for due process of law in their administration" (p. 147).

National Immigration.

Studies on the eugenical aspect of immigration were continued in collaboration with the Committee on Immigration and Naturalization of the House of Representatives and the Department of Labor of the United States Government. On November 21, 1922, the results of the studies up to that date, with particular reference to the relation between social inadequacy and modern immigration, classified according to race and specific type of disorder, were laid before the House Committee on Immigration. These were published under the title, "Analysis of America's modern melting pot" (pp. 725 to 830 of the hearings before the Committee on Immigration and Naturalization, House of Representatives, sixty-seventh Congress, third session, serial 7–C). These hearings comprise an analysis of the detailed diagnostic and racial returns from 445 State and Federal institutions for the socially inadequate classes. In these institutions which collaborated in the study were found a total of 210,835 inmates (date of returns being from January 1, 1921, to March 31, 1922). The particular classes studied were as follows:

The feeble-minded, all types; the feeble-minded, the moron group; the insane, all types; also the dementia præcox group; the manic depressive group; the senile psychosis group; the criminalistic, all types; the criminalistic juvenile group and adult group; the epileptic; the inebriate; the tuberculous; the blind (including the "blind and deaf"); the deaf; the deformed; the dependent, all types, children and adults; all classes of the socially inadequate as a unit; the feeble-minded (census of 1920, survey of 1921) and the insane, all types (census of 1920, survey of 1921).

The analysis was made on the basis of quota fulfillment; each nation and nativity group was allotted an expected quota for each type of degeneracy, based upon the total relative numbers of persons of the particular racial or nativity group in the whole country according to the census of 1910. The quota fulfillment shows a comparison between the number of persons expected and the number found in State and Federal custodial institutions.

The results logically deducible from this particular investigation show that in reference to nervous stability and social adjustment the immigrants who represent the present foreign-born population of the United States are much more poorly equipped, mentally and physiologically, than the immigrants whose blood is to-day represented by the group "Native White, both parents native-born." Further, the immigrant himself is better individually than the germ-plasm which he carries and from which his children develop. This shows particularly in the case of the feeble-minded, who themselves, while legally being entirely excludable, showed a quota fulfillment of 21.56 per cent ± 1.25, while the native white, both parents foreign-born, show a quota fulfillment of 165.39 per cent ± 1.34. The native white, one parent native, one foreign-born, show a quota fulfillment of 190.27 per cent ± 2.05.

Representing the House Committee on Immigration as expert eugenics agent, and the United States Department of Labor as special immigration agent to Europe, Dr. Laughlin sailed for Europe August 8 to make studies in several of the European countries on the possibility of determining, in the home towns and the ports of departure, the facts concerning the hereditary qualities and social values of would-be immigrants, and to determine, further, the probable cost to the United States Government, per would-be immigrant, of such practice, should it be enacted into law.

During the spring and early summer of 1923, Mr. A. E. Hamilton, formerly associated with the Eugenics Record Office, made studies on immigration in collaboration with the Eugenics Record Office and Hon. James J. Davis, Secretary of Labor, at the expense of the Department of Labor. These studies were based upon the records which we have accumulated, and were on the subject of the several aspects of selective immigration.

THE PHYSIOLOGY OF REPRODUCTION AND DEVELOPMENT.

Modification of Length of Œstrus Cycle by Means of Alcohol.

As described in the Year Book for 1921, Dr. E. C. MacDowell found that when both parent rats were given alcohol before and during mating they produced nearly 11 per cent fewer progeny in a litter than their full brother and sister controls. Moreover, in an equal period of time the alcoholized parents produced 0.72 litter per pair, while the unalcoholized mice produced 2.07 litters per pair. Thus the alcoholized parents had about one-third as many litters and seven-eighths as many young to the litter as the unalcoholized. Consequently, in a struggle between the two kinds of parents, the former would tend to succumb through insufficient numbers. An approach to the problem of the influence of alcohol upon the prolongation of the interval between litters, hence probably of the œstrus cycle, was provided by the notable work of Long and Evans on the œstrus cycle of the rat and of Edgar Allen on that of the mouse. These workers show that the method of vaginal smears is adequate in measuring the œstrous cycle. Dr. MacDowell is continuing work on the causes of reduced fecundity of the alcoholic mice. He reports as follows:

"Mice have been used in the present study on account of the larger number that can be raised in the same space and on the same food as rats. Daily vaginal smears are taken by means of a very small swab and examined microscopically after staining in hemotoxylin and eosin. The alcohol has been given by the inhalation method as before, but instead of tanks holding numerous animals, a pint milk-bottle has been used for each mouse; a measured amount of alcohol is poured over a standard-sized piece of paper toweling which is then slipped into the bottle after the mouse, and a regular milk-bottle stopper is inserted and the bottle inverted. The controls, which live in the same boxes with the corresponding treated mice, are handled in the same way, with the omission of the alcohol. Three series of experiments have been in progress: (1) Starting when the mice are a month old, they have been placed in bottles with 3 c.c. alcohol on the paper every day for 45 minutes, called the light dose; (2) month-old mice have been given the 3 c.c. dose every day until they were motionless and did not move when the bottle was rotated, called the heavy dose; (3) starting after a series of normal cycles had been obtained from the mice as adults, the dose of 3 c.c. for 45 minutes was given, and later in some cases the heavy dose was given.

"So far the following numbers of mice in the respective series have been studied: 50, 13, and 11. The average number of observed cycles per mouse is 5. When the treatment is started early and given for 45 minutes per day, the summaries of the results obtained show *no general modification of the length* of the œstrous cycle in the treated mice compared with their untreated sisters. The time of the original opening of the vagina and the time before the first observed œstrous seem to be equally unmodified by the light treatment. The number of cycles so far obtained from the young ones given the heavy dose is too small to venture a preliminary conclusion. Although there may be no general effect shown by the alcohol treatment, there are marked individual cases that appear to indicate marked effects; giving records of

66 or 69 days, records unapproached by any of the control mice, whose modal cycle-length was 6 days. Similar individual differences are shown by the records of the mice treated after their normal cycle-length was tested. Some appear to show that the treatment changed the length of the cycle, and in others there was no change. This is true of both light and heavy doses.

"Although under the conditions of the experiment alcohol does not seem to have a general or specific influence upon the length of the œstrous cycle, these preliminary findings seem to support the proposition that alcohol influences the length of the œstrous cycle in certain females. This is the situation called for by the data from the rats, a selective action on the mothers themselves. It is to be noted, however, that the rats were given a daily intoxicating dose, and the greater part of the observations so far made upon the mice have been from relatively light dosage."

Recognizing the possibility that different strains of mice may give different characteristic cycle-lengths, an investigation has been begun into the normal length of the œstrus cycle in 10 of the different strains and families at hand. Already, in preliminary fashion, it may be announced that the different lines do, indeed, show differences in the frequency distributions of their cycle lengths. Combining all distribution curves, the mode is found to lie at 5 to 7 days.

A separate study was made of the vaginal smears of 5 yellow mice, a race characterized by an enormous deposition of fat. Yellow mice are also slow breeders. Whether or not the failure of the fat yellows to breed is due to the cessation of œstrus is uncertain. Of the 5 mice, 4 gave fairly regular cycles, averaging 10 days; 1 was examined for 80 days and showed only 3 questionable œstrus periods.

The analysis of the effects of alcohol upon reproduction is being carried further by counts made upon the corpora lutea of pregnancy in living animals. In the case of the rats, formerly studied, the number of young per litter was reduced in the treated animals; but it was not determined whether this was due to a reduction of eggs ovulated or to prenatal mortality. Since the number of corpora lutea formed at one ovulation closely approximates the number of eggs set free, the difference between the number of corpora lutea of any pregnancy and that of young born gives the amount of prenatal mortality. Dr. MacDowell has developed a special technique for finding this difference. During any pregnancy the number of copora lutea belonging to this pregnancy can be readily counted by exposing the ovaries to view, for at this time the corpora lutea of pregnancy are very large, red, and prominent, while all of the older corpora are small, of an opaque cream-color, and sunken into the body of the ovary. The effects of the operation of exposing the ovary are very slight; the young are born normally, even on the following day, with no increase in natal mortality. The operation may be performed repeatedly on the same female without interfering with her subsequent reproductive functions. In normal pregnant mice, 49 operations gave satisfactory counts of the recent corpora lutea in both ovaries; they averaged 8.7 per female. The number of young born to these females after operation averaged 6.4, which may be compared with 5.8, the average given by 1,509 litters in the whole colony. The seven operations on alcoholized mice so far performed indicate that the light dosage does not modify the number of ova liberated.

In connection with the observations on the number of corpora lutea in alcoholized and unalcoholized mothers, certain studies have been made on modification of the number of eggs ovulated in any œstrus cycle. One of these concerned the influence of removal of one ovary on the number of eggs subsequently ovulated. The left ovary was removed by Dr. MacDowell from 50 adult female mice; subsequently the animals were mated and counts made of the corpora lutea. The question has been investigated before, and it had been found that the single ovary compensates for the loss of its mate. In our experiments the number of corpora lutea in the remaining ovary average about 1 greater than the average produced by two ovaries in our normal females. Thus the single ovary fully compensates and, perhaps, even overcompensates. However, the number of young born from semi-spayed mothers (4.6 per litter) was less than from normal females of the same strain (5.6 per litter). This reduction in the number of young which come to birth is probably an adjustment to the limitations of space in the single horn of the uterus in which all of the young must develop, since passage of embryos to the opposite horn is mechanically almost impossible.

Blood-Sugar Values in Generic Crosses.

As was stated in our report for the last year (Year Book for 1922), Doctors Oscar Riddle and H. E. Honeywell have cooperated in studying the inheritance of blood-sugar values in hybrids between the Japanese turtle-dove (*Turtur orientalis*), which has on the average about 188 mgm. of sugar per 100 c.c. of blood, and the ring-dove (*Streptopelia alba*), which has an average of 149 mgm. of sugar per 100 c.c. of blood. The F_1 hybrids have an intermediate amount of blood sugar. This year further progress has been made on this topic. F_1 hybrids have been obtained between a *Spelopelia* and *Streptopelia*, and these, likewise, show a blood-sugar value that is intermediate between those of the parent genera.

The F_1 hybrids of *Turtur*×*Streptopelia* have been back-crossed to *Streptopelia*, and the hybrids of this generation give an average blood-sugar value that is intermediate between that of the F_1 and *Streptopelia*. The blood-sugar value is apparently inherited in the same way as body-size. It is a complex of several factors, and, it may be predicted, will follow the rules of multiple-factor inheritance. Dr. Riddle points out that the new sugar values found in the hybrids are maintained throughout life, and that such a different value requires new adjustments of equilibrium on the part of all tissue components throughout the developmental period of the hybrid; also, that these adjustments supply one possible basis for various irregularities in the behavior of characters in hybrids derived from wide crosses.

Relation of Reproductive Overwork to Carbohydrate Metabolism.

Last year this Department reported new light upon the mechanism of "reproductive overwork" through the discovery that the suprarenal glands of female pigeons undergo marked and prolonged hypertrophy in very exact coincidence with each ovulation period, and by the further observation that the carbohydrate metabolism of the bird undergoes a simultaneous change, as shown by an increased concentration of the sugar of the blood. These results have been extended, confirmed, and published by Dr. Riddle. The conclusions drawn from the studies on suprarenal hypertrophy are as follows:

"In four kinds of healthy doves and pigeons the weight of the suprarenal glands has been found to increase at each ovulation cycle and the point of greatest increase is coincident with the act of ovulation. The mean size increase found in the four groups was approximately 40 per cent. The diseases commonly met with in our birds usually produce very marked suprarenal hypertrophy; and all birds with disease recognizable to us have been separately classified and tabulated as diseased birds. Without this separation of healthy and diseased birds a definite relation of suprarenal hypertrophy to ovulation could scarcely be obtained from any reasonable number of birds by our method of study, since the glands of diseased birds are extraordinarily variable in size.

"Previous studies on suprarenal hypertrophy during pregnancy and lactation have apparently overlooked hypertrophy in connection with ovulation; if the latter occurs also in mammals, this is a possible source of error in many results reported. The changes in the suprarenals of mammals at ovulation should be investigated. The suprarenals of male pigeons are probably slightly larger than those of females, even after fully correcting for differences in body-weight.

"When doves are provided with heated quarters and are made to reproduce throughout the year, as were the birds used in this study, it does not appear from the considerable data at hand that season is in itself associated with any change in suprarenal size. If such seasonal changes do occur they do not affect the results reported. Adequate histological studies have not yet been made, but it is probable that both medulla and cortex share in hypertrophy at ovulation.

"These results constitute a contribution to our definite knowledge of the conditions associated with previously observed changes in size of ova, of sex-ratios, and of sexual development in the offspring of pigeons made to reproduce rapidly and continuously throughout the year. They demonstrate that some elements of a new and intimate environment are provided for ova thus made to develop under prolonged and nearly continuous suprarenal hypertrophy."

The studies on the changes in blood-sugar concentration which accompany the suprarenal hypertrophy described above have been made in collaboration with Dr. H. E. Honeywell. These studies have led to the following conclusions:

"Each ovulation period in the pigeon is accompanied by an increase of approximately 20 per cent in the amount of sugar in the blood. The sugar-content of the blood begins to increase at about 108 hours preceding the ovulation of the first egg; it is then maintained at the highest level until the second ovulation 44 hours later; following this period it probably gradually declines to the normal non-ovulation level in an additional 108 hours—unless new ova meanwhile begin their final period of rapid growth and a new ovulation cycle is begun. The curve which thus describes blood-sugar values as related to ovulation is essentially similar to the curve for suprarenal hypertrophy at ovulation earlier described by Riddle. The above results apply to various species of doves, pigeons, and their hybrids. Female pigeons forced to rapid and continuous ovulation throughout the year are thus forced to an almost continuous maintenance of their bodily functions—and to the production of their eggs—under altered and unusual conditions as regards their carbohydrate metabolism."

Relation of Storage Metabolism to Insulin.

Dr. Riddle has made further experiments on this matter with the thyroid secretion referred to in my last report and gets only confirmation of the results reported previously. Insulin, the incretion of the pancreas which increases the rate of carbohydrate metabolism, has also been found to decrease the size or storage metabolism of the ova. Mr. Walter Fisher has collaborated in this study. It was found that a dosage compatible with continued ovulation, and strictly limited to twice-daily injections during the last half of the growth period of the ovum, reduced the size of ova of 9 birds during a season by 2.8 to 5.7 per cent; and that the portion (one half) of these eggs which was subjected to the effects of insulin during 40 hours longer than the other half showed a further reduction of 4.1 per cent.

From the first of his studies Dr. Riddle has been led by other kinds of evidence to interpret high storage values of the yolk to mean low oxidizing capacity. Still further confirmation of this interpretation has, therefore, been obtained from both of the above studies. Other earlier work has shown a correlation of large yolk-size with femaleness and of small yolk-size with maleness in the embryos arising from such yolks.

Origin of Single-Yolk Twins.

Out of approximately 20,000 incubated eggs of doves and pigeons there have arisen 8 cases of twin embryos, all apparently well formed. These twins arose out of stock so closely watched and intensively studied as to afford very exceptional information concerning the conditions attending their origin. A control is afforded by the simultaneous determinations of yolk-weights in 20,000 cases, yolk-analyses in 1,300 cases, and bomb-calorimeter measurements of energy storage in 500 other eggs. Compared with the control, 5 of the yolks that gave rise to twins were of extremely large size and 3 were of extraordinarily small size. There is no reason for thinking that the twin production was caused by an accidental cooling of the blastoderm, a condition suggested by Stockard as the real cause of twin production in the fowl. Indeed, the experimental subjection of 231 embryos obtained at from 4 to 24 hours of prematurity (Year Book, 1922, p. 121) to low temperatures before and during gastrulation yielded no case of double embryos, though it did produce other kinds of abnormalities. Indeed, not only retardation but also acceleration of the developmental rate produces such abnormalities. The large twin-producing ova were doubtless examples of an extremely low metabolic rate in the unsegmented ova, and the small ova were examples of an extremely high metabolic rate. Twins arose in these eggs as a result of this retardation or acceleration already present in the ovum at the time it left the ovary.

Among agents that induce abnormalities and monsters in early embryos of the pigeon, high concentration of carbon dioxide comes first, then increased concentration of oxygen, decreased oxygen, and low temperature last. During the first 2 to 4 days of development after laying it is the youngest stages that are most affected by increase of carbon dioxide and of oxygen. The later stages are relatively more effected by low temperature. Evidence is supplied that a temperature of 39.4° C. (103° F.) is higher than the optimum and produces a stimulating or accelerating effect during the first 12 to 24 hours of development after the egg is laid. Probably in consequence of this accelerated development, the subjection of embryos during this first 24 hours to exceptionally lowox ygen pressure results in a low survival rate, and exceptionally high oxygen pressure results in a high survival rate.

The results of these studies support and extend the conception that both abnormalities and twins owe their origin to alterations of the developmental rate, or perhaps the metabolic rate, at various and unequally susceptible developmental stages. But whether a stage is "critical" or "indifferent" in Stockard's sense depends in part, at least, upon its modifiability by a retarding or an accelerating agent, and the stage of development at which twins or multiple embryos actually arise extends all the way from the unsegmented egg to gastrulation.

Relation of Blood Sugar to Ovulation.

Dr. Oscar Riddle, with the cooperation of Dr. H. E. Honeywell, has shown that at each ovulation period there occurs a distinct suprarenal hypertrophy and concomitantly a rise in the concentration of the sugar of the blood. It has seemed probable that measurements of the blood sugar might throw light on the causes of diminished or suppressed ovulation. Studies on this subject were undertaken both because of the practical and the theoretical importance of a knowledge of the factors which regulate egg production. The practical importance is obvious, inasmuch as fecundity enters in one way or another into most genetic studies. The theoretical importance to our sex studies we have long recognized, since different sex-ratios are obtained from pigeon clutches according as they are separated from preceding clutches by long or short intervals.

A year ago Drs. Riddle and Honeywell reported (Year Book, 1922, p. 121) that one condition that inhibits ovulation, namely, inactivity or confinement in small space, reduces within 3 weeks the blood sugar of common pigeons from 0.180 to 0.125 per cent. Such pigeons produce few or no eggs. During the present year the same investigators have shown that the onset of cold weather also causes a distinct fall in the blood-sugar values of several kinds of pigeons. The duration of the initial decrease is, however, neither long nor constant. This period of decreased sugar values is one of decreased ovulation rate in our entire collection of birds.

These points established, Dr. Riddle injected insulin into the pigeons; this lowered the blood sugar and nearly all ovulations were inhibited. Precisely, the dose of insulin used lowered the blood sugar of ring-doves from 0.149 per cent to about 0.080 per cent during 1 to 4 hours twice daily. Under this treatment only about one-tenth of the normal or expected number of ovulations was realized. In the course of this study it was learned that ova which have approached to within 48 to 72 hours of ovulation are not suppressed by this dosage of insulin, and this led to a study of the effects of insulin on the size of ova. These studies seem to establish the principle that conditions which lower the concentration of sugar in the blood are incompatible with ovulation.

Death of Embryos in Eggs Abnormally Retained in the Oviduct.

Various students of poultry have observed that an occasional fresh-laid egg of the common fowl already contains a live or dead embryo of one, two, or three days of growth. In these cases it is obvious that such eggs were retained or delayed within the hen's oviduct during at least the period represented by the age of the embryo. Why some of these embryos are dead and others alive is a question which seems never to have been investigated.

In our own studies, and in all genetic work with birds, it may be of importance to know the cause of failure or death in all eggs or embryos which fail or die. For example, in some pigeons the two eggs of the pair or clutch have unequal prospective sex values, and in any complete analysis of sex-ratios in these forms it is necessary to know whether the first or the second of the clutch is more subject to delay and consequent death. Dr. Riddle has, accordingly, carried out and published a study the full purpose of which was to determine if the retention of eggs in the oviduct is a source of embryonic death; to find out the factor immediately responsible for the death; to measure the amount of death from this cause; and to evaluate the extent to which these eliminations by death may affect sex and genetic ratios obtained in pigeon breeding. In the published results the following conclusions were reached:

"Approximately 1 egg of each 100 produced by a collection of doves and pigeons has been found to be abnormally retained in the oviduct for periods varying between 5 and 122 hours. The retention or delay of eggs within the oviduct of doves during more than 5 hours results in the death of about one-half of the embryos. About 0.5 to 0.6 per cent of all embryos die as a result of egg-retention in the oviduct. Death usually occurs at or near the 0.5-day stage of development. Increased frequency of death occurs in the eggs longest delayed and in eggs provided with thickest shells. Death probably results from an oxygen supply inadequate to the increasing requirements of the post-laying embryonic stages thus retained in utero.

"The occasional survival of retained embryos during these early developmental stages is a result of specially favorable respiratory conditions, namely, the presence of a thin shell or a delay in the secretion of the normal amount of shell.

"An egg occasionally remains in the shell gland during two or three times the normal period for shell secretion without obtaining more than the normal amount of shell. More commonly eggs thus retained receive a heavier secretion of shell material.

"The retention of a 'first' egg of the clutch or pair often or usually results in the suppression of the second egg of the pair. The total result is the death or elimination from breeding data of approximately one-half of the embryos of both eggs of such pairs.

"The retention of a 'second' egg of the pair suppresses no later ovulation. This retention of a second egg occurs, however, only once in 200 ovulations, and approximately one-half of these retained embryos survive. The selective elimination of so small a number of second eggs can have but slight effect on the sex-ratio. Even in pure species, where second eggs of the pair are predominantly female-producing eggs, the proportion of females to males is affected from this source by probably less than 0.3 per cent."

Parthenogenetic Cleavage and the Origin of the Subgerminal Cavity in the Pigeon's Egg.

The close observation of all infertile eggs encountered in Dr. Riddle's pigeon breeding indicated that such eggs give evidence of the presence of a "subgerminal" cavity—a condition normally associated with an early stage of embryonic development. It had also been learned that the yolks of such incubated infertile eggs absorb very appreciable amounts of water. The interest of Professor G. W. Bartelmez, Department of Anatomy, University of Chicago, was enlisted in the appearances connected with some such infertile eggs obtained from "virgin" females, with the result that parthenogenetic cleavage in these eggs was demonstrated. This parthenogenesis in birds is of course a fact of genetic interest, not only because it is found in our own genetic material, but because it strongly supports Lecaillon's report of parthenogenesis in the fowl. The mode of origin of the subgerminal cavity as this could be learned from pigeon eggs is of real interest to developmental physiology. The results which have been written and sent to press were abstracted as follows:

"Incubated unfertilized pigeons' eggs acquire a fluid-filled space in the region normally occupied by the subgerminal cavity, and another—peripheral to the germ disk—beneath the vitelline membrane. This increase by osmosis of its water-content at the expense of the surrounding albumen begins in fertilized and unfertilized ova alike as soon as the ovum is liberated from the ovary. This increased fluidity is observable at all points immediately within the vitelline membrane and in the space normal to the subgerminal cavity.

"Early cleavage stages occur parthenogenetically in the pigeon's egg. Cleavage proceeds only to a stage approximately equal to that attained 10 hours after fertilization in normal development. The degenerative changes which follow are closely confined to the segmented region, and these are accompanied by a pronounced increase of fluid beneath the segmented area. The development, therefore, stops at a stage preceding that at which the subgerminal cavity normally arises, but the cavity forms nevertheless. This cavity in such eggs, therefore, arises not as a result of 'development' but as a result of a progressive increase of water within the ovum. The origin of the subgerminal cavity is thus given a purely mechanical explanation."

Relation of Age, Sex, Species, and Certain Diseases to the Blood Sugar of Pigeons.

After Dr. Riddle found the measurement of the sugar of the blood a most convenient method of studying certain metabolic aspects of sex and of reproduction in pigeons, it became necessary to learn the sources of error and variability in this material. In collaboration with Dr. Honeywell he has made about 1,400 sugar determinations. As a result of this study it has been possible to eliminate several sources of error from their own published data; to demonstrate some hitherto unrecognized sources of error in blood-sugar determinations; to evaluate the relation of age and sex to the normal blood sugar in the pigeon better than it has been done in any other species, with the possible exception of man; and to supply, for this aspect of the carbohydrate metabolism, the fullest data now available for any order of animals.

OTHER INVESTIGATIONS.

Physico-Chemical Properties of Plant-Tissue Fluids.

As has been emphasized in preceding reports, the cellular fluids represent at the same time the product and the environment of the protoplasm. It is under the influence of these fluids that all the vital processes, cytoplasmic and nuclear, must take place.

A series of investigations by Dr. Harris and a number of collaborators during the past several years has shown wide variations in the physical and chemical properties of plant-tissue fluids. Such properties as osmotic concentration, specific electrical conductivity, hydrogen-ion concentration, and the concentration of other ions have been shown to differ not merely from flora to flora, when these are growing under different environmental conditions, but to be characteristic of species so closely related that genetic studies may be made upon them when growing under the same conditions.

Brief reports on the various phases of this work have been made in preceding Year Books. During 1922 and 1923 progress has been made along the following lines:

Tropical Element in North American Flora.

Evidence is gradually accumulating that the intrusion and persistence of the West Indian element in the flora of subtropical Florida is due in part to the physico-chemical properties of their tissue fluids. During the winter of 1922, Dr. Harris, assisted by C. W. Crane, made extensive series of determinations in southern Florida, extending as far as Flamingo in the Cape Sable region. Here conditions remarkably similar to those investigated in the Jamaican coastal deserts by Harris and Lawrence a number of years ago were encountered.

Selective Elimination of Species Due to Changes in Salinity of the Soil Solution.

The opening of Jupiter Inlet on the Florida east coast, after it had remained closed for several years, has given an opportunity to consider the action of natural selection with respect to sap properties. The considerable areas of fresh-water swamp which will be occasionally touched by salt water had already been studied by Dr. Harris to some extent, and the sap properties of the species which are growing under these conditions are known. Future observations will determine to what extent the elimination of species is dependent on their sap properties, and to what extent the sap properties of other species change with the modification of conditions.

Other Studies on Natural Vegetation.

Such measurements on the sap properties of alpine and desert plants as could be made incidentally to experimental work in Utah and Arizona have been carried out by Dr. Harris. The time demanded by experimental studies is rapidly rendering this environmental work difficult, and it will soon be brought to a close as a major project, and be continued only incidentally to experiments under way in the various regions.

A report on the investigations in the highly saline and other environments of Tooele Valley, Utah, on the southern shore of the Great Salt Lake, reviewed in a preceding Year Book, has been completed for publication.

Investigations on the Cereals.

As noted in preceding reports, Dr. Harris has made investigations on the physico-chemical properties of wheat and other small grains in the arid region of the Great Basin since 1920. These studies have been made possible by the U. S. Department of Agriculture with the cordial but informal cooperation of the Utah Agricultural Experiment Station and Agricultural College.

From 1920 to 1922, inclusive, attention was devoted primarily to the change which takes place with the advance of the season when the various varieties are grown with and without irrigation. These studies have, however, involved preliminary comparisons between fall and spring wheats, and general comparisons between the varieties. This phase of the work is now in an advanced stage of preparation for publication. In 1923 the purpose of the work was changed so as to deal more intensively with the differentiation of various varieties and selections with respect to drought resistance. During 1923 the field work was mainly in charge of Mr. W. F. Hoffman, of the University of Minnesota, assisted by Dr. G. O. Burr, Mr. W. B. Sinclair, and Mr. Charles W. Crane, Dr. Harris going to the field only toward the end of the season.

ADMINISTRATIVE RECORD.

ARCHIVES OF EUGENICS RECORD OFFICE.

The care of the archives has remained in the hands of Dr. Elizabeth B. Muncey, who has been assisted by Misses Helen Bowen and Margaret Martin as indexers. An estimate of the extent of the records and their index as of September 1, 1923, is as follows: 961,271 cards in the index, 1,618 books in the archives. The field reports (F) and (V) number 59,250 sheets, the special-traits file (A) 25,068 sheets, the records of family-traits (R) and (M) files, 5,658 parts. During the summer we had the assistance of the members of the training class in preparation of materials for the archives and in the arranging of the records. Misses Harriet Abbott, Grace Allen, Ann March, and Beatrice Meyers collated data on extinction of families, heredity of exostoses, and other topics.

The archive room is full to overflowing and, indeed, the entire Eugenics Record Office building has nearly reached the limit of its capacity. There is urgent need of an addition to it.

Collection of Data.

More records than ever before have come to the Eugenics Record Office through the generous cooperation of college and university professors. There were 852 Records of Family Traits thus supplied, besides 2,130 other schedules, nearly all filled out with great care. The number of teachers and institutional directors who thus collaborated was 42. The Record Office is deeply grateful to these collaborators for their cooperation.

Training Corps.

10 women and 3 men were trained for eugenical field work from June 27 to August 7. Of these, 4 have secured or are considering appointments in eugenical field work. To date, 246 persons have received this training.

Special Activities of and Changes in Staff.

The Director was absent on a trip to Europe September 13 to October 30, 1922. He visited the leading centers of genetical research and returned impressed by the courage with which men of science in Europe are continuing their researches against great odds, and by the great responsibility devolving on American geneticists to produce results proportional to their relatively great opportunities.

On August 8, 1923, Dr. H. H. Laughlin sailed for Europe to attend the meeting of the International Commission of Eugenics, at Lund, Sweden, and to make studies on immigration. During his absence Dr. Banker assumed some of the duties of the Assistant Director of the Eugenics Record Office.

GEOPHYSICAL LABORATORY.[1]

Arthur L. Day, Director.

Both science and story have left the interior of the earth virtually a closed book. Imaginative writers have forecast many of the conquests of the sea and of the air and of the regions beyond, but the interior of the earth remains inaccessible to them; scientific effort has often been consciously and even eagerly directed toward it, but has revealed scarcely more. The distance from the surface to the center of the earth is some 4,000 miles, of which hardly more than a mile has been actually explored. What properties or what substances even a few more miles might reveal is a matter for inference alone, inference for the most part with a very inadequate if not an insecure foundation of fact. And, further, the number of productive inferences is so small and their scope is so limited that they furnish little material or encouragement for more elaborate study.

We learned, for example, long ago from the astronomers that the density of the whole earth as a body and a member of our solar system was about five and one-half times that of water, while the geologists, studying its surface, found only rocks of a density varying from two and one-half to three and a quarter times that of water. The part of the earth which we know is much lighter than the average of the whole, and the unknown interior must therefore be different and heavier. The study of the tides and of the figure of the earth, and even more particularly the discovery and measurement of a tidal motion in the crust of the earth itself, revealed the fact that the earth structure must be about as rigid as steel, from which it is a short step to infer that the major portion of the interior may be of iron; we do not know. Its density (about 8) would seem appropriate. Some further support has been found for this inference from the nearly universal distribution of iron in all known rocks and from the fact that meteors often come to us which are composed almost entirely of it. The manner of transmission of earthquake shocks through the earth may perhaps be considered to offer some support also, though here the interpretation is more hazy.

We also know that the temperature within the earth increases at a fairly regular rate as we go down. In most regions it has already become too hot for human activities at the depth of a mile and in some localities very much sooner than that, so that no amount of boring skill will ever enable us to visit the earth's interior. We must recognize as a further consequence that this continual increase in the temperature downward and the parallel increase in the weight of the overlying mass will speedily bring us to temperatures and pressures which are also beyond the reach of experimental study in the laboratory, and in consequence of this the effects of such pressures and temperatures upon the earth-forming materials at great depths can not be clearly predicted.

Most fruitful in possibilities for future thought and exploitation, because it directly concerns the 40 or 50 miles of the earth's shell next below the very thin outer one which our mine-shafts reach, is the recently proposed theory of the isostatic adjustment, within the crust of the earth, of differences of loading, due (1) to the mountains and the gradual transfer of their material to the sea by erosion, (2) to the considerable differences in the density of the surface rocks themselves above referred to, and to other causes. This theory, singularly well supported by the thousands of measurements of the force of gravity at different points, suggests that all these differences of loading, variable as they are with mountain-building and erosion, great ice-caps which some time covered polar and temperate zones and passed away, are completely equalized through some manner of subsurface adjustment within 40 miles or so of the surface. It is as if blocks of heavy wood and cork, soap, and toy balloons were floating together upon water, some projecting high above the surface and some nearly submerged, but the effect of each individual load upon the water completely equalized a foot below the surface.

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[1] Situated in Washington, District of Columbia.

This is not an appropriate place to pursue this most interesting subject, interesting especially, perhaps, because of its inaccessibility to direct observation, but even so brief an introduction may serve to indicate how slender and indirect these inferences are, and to explain the eagerness with which every thin ray of light is sought and followed which may conceivably help to penetrate the dense blackness which hides from our understanding the interior of the earth. Such a ray of light has appeared during the past year in the course of our studies of the compressibilities of the rocks under high pressure.

Perhaps the most important aspect of pressure as a factor in geologic processes is in its power of holding gases, carbon dioxide, water vapor, etc., in solution in the liquid magma and so influencing both the mineral composition and the manner of crystallization of the rock which forms from it; but the effects of pressure *per se* are important also, both during the formation process and afterward when exerted upon rocks which differ considerably in their elastic constants. Among the individual effects of such pressures are the production of new and denser forms of minerals under the conditions of high pressure existing even at relatively shallow depths in the earth's crust and the change of density of the rocks and minerals themselves at different depths. These two factors are best investigated by direct measurement of the decrease in volume for a given pressure, i. e., the compressibility.

The volume change of a mineral or rock under pressure is difficult to measure because it is so small; a pressure of one atmosphere decreases the volume of an ordinary rock by only one or two millionths of the original volume. With many rocks porosity introduces a further complication. Heretofore the compressibility of rocks has been determined only by an indirect method, but we have been able to measure the volume change directly under hydrostatic pressure. This is made possible by working at very high pressures and by inclosing the rock specimens (which are surrounded by liquid) in a thin jacket of soft metal. The technic of high-pressure experimentation no longer encounters the formidable difficulties which once seemed nearly insurmountable; and, with hydrostatic pressure, measurements can be obtained at much higher pressures than by the indirect method. Furthermore, soft rocks of imperfect elasticity are just as amenable to measurement as the harder and more elastic rocks. Altogether, we have now measured the compressibility of 40 materials up to pressures equivalent to a depth within the earth of 25 miles.

From compressibility we are able to pass to another elastic property, the rigidity, and to assign a value to the rigidity of any rock whose mineral content is known. The rigidity of a granite is the smallest of the typical igneous rocks; gabbros occupy an intermediate position; and when we note that the rigidity of an ultra-basic rock, e. g., a peridotite, is two-thirds as great as that of steel, we no longer find it so difficult to see how the crust of the earth can be nearly as rigid as steel. How temperature influences these values has not yet been determined. This is probably a small effect, but we hope that we may be able to measure the effect of high temperature on volume change and on elasticity in general.

With a knowledge of the elasticity of a specified rock at a specified depth, we have in our hands a powerful instrument for determining the character of the rocks at each level in the earth's crust. For, from the velocity of transmission of earthquake waves, we obtain a value for the elasticity of the rocks at a specified depth, and by combining the two sets of data we can state the nature of the rocks not only near the surface but to a certain extent in the very interior of the earth. The velocity of transmission of earthquake waves, especially for the shallower depths, is known none too well; but taking the best data available, the initial velocity of the faster waves is about 7 km. per second. Now, from our compressibility measurements, the velocity of such a wave in a typical granite is 5.6 km./sec. and in a typical gabbro is 6.9 km./sec. Hence, if we place any confidence in the seismic data for near-by earthquakes, it is evident that the granitic layer is a mere film on the earth's surface—so thin, indeed, that where considerable depths are involved it may be neglected.[1] The main part of the so-called crust of the earth is, therefore, at least as basic as a gabbro, and possibly more like a peridotite. Thus, very indirectly, and somewhat adventitiously, our information about the interior of the earth is gradually widened.

The compressibility of a substance is connected with the forces between the atoms and will eventually be of value in the study of atomic structure. Already the close correspondence between our value for the compressibility of diamond and the value calculated by Sir J. J. Thomson in accordance with his theory of atomic structure is of considerable interest.

It is our purpose, if the opportunity can be provided (Year Book 20, p. 11; Year Book 21, p. 12), to undertake a much more thorough study of these elastic constants of the rocks through as great a range of temperatures as possible, and so to determine, with as much certainty as we may, the constitution of the earth beneath our feet. Pressures equivalent to a depth of 25 miles and temperatures equivalent to a depth perhaps of 50 miles are now within the reach of laboratory experiment.

It is also a part of the program of the Advisory Committee in Seismology, of which a report is submitted on a later page, to develop apparatus for a much more critical study of the manner and speed of transmission of local earthquake shocks than has heretofore been possible. These two undertakings together offer great promise of yielding real information about the interior of the earth through experimental study and measurement. Should it prove practicable to define such measurements explicitly through transmission of artificial earthquakes set in motion by high explosives in known rock masses, the method would seem to be both direct and quantitative.

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[1] Recent calculations from data obtained from the Oppau explosions indicate a granite layer some 15 km. thick (Dorothy Wrinch and H. Jeffreys, Roy. Astr. Soc., M. N. Geophys. Supplement 15–22, 1923).

PETROLOGY OF HAWAIIAN ISLANDS.

As an outcome of the First Pan-Pacific Congress, held at Honolulu in 1920, a study is being undertaken of the Petrology of the Hawaiian Islands. For this there is available the largest collection of Hawaiian lavas that has yet been brought together, including many specimens collected by H. S. Washington in 1920, a large collection made by Dr. Sidney Powers, and smaller collections made and contributed by several other geologists. These specimens, which number about 1,500, represent very well all islands of the group.

The study of the five volcanoes (Kohala, Mauna Kea, Hualalai, Mauna Loa, and Kilauea) on the island of Hawaii has been completed and the results have been or are being published in a series of papers in the American Journal of Science for 1923. The study embraces petrographical descriptions and many new chemical analyses, which bring out clearly the characters of the different types of rock and their relations to each other at the different volcanoes. The relative ages of the five volcanoes are discussed, and it is shown that each one differs more or less from the others in the general and in the detailed characters of its lavas. It is shown that, although the Hawaiian lavas are for the most part basaltic, yet there are some very significant differences even within this comparatively narrow range. Also, light is thrown on the affinities and probably the origin of the very alkalic rocks (trachyte and oligoclasite) of Hawaii, and on the origin of some very basic olivine-rich lavas that are near the other extreme. The study of the Hawaiian lavas furnished many excellent illustrations of the validity among natural lavas of Bowen and Andersen's experimental observations on the origin of olivine, which were made in this Laboratory some years ago (Publication No. 172). The studies lead also to an explanation of the cause of the differences between the two chief types of basaltic lava—aa and pahoehoe—which are very common at the Hawaiian and other volcanoes, and for which no adequate explanation has yet been given.

The study is being prosecuted and extended, with the addition of many more analyses, to the lavas of the other islands of the group, and should be completed in 1924, when the final conclusions based on the complete data will be discussed. The results already obtained throw light on certain problems of the petrology of the other volcanic islands of the Pacific, indicating that the lavas of the Hawaiian Islands probably represent the lavas of many of the intro-Pacific islands fairly well. It is therefore of importance, both for our knowledge of the Pacific volcanoes and of volcanoes in general, that the present studies be continued and extended. It is desirable that the study of many specimens of lavas from the Pacific volcanoes, especially a large number collected by the late Dr. J. P. Iddings and by Professor W. H. Hobbs, be not unduly delayed.

VOLCANO STUDIES.

In the annual report of last year there was reviewed at considerable length the first of a series of papers on the volcano and fumarole activity associated with Katmai Volcano, Alaska (Paper No. 485, E. T. Allen and E. G. Zies, "A chemical study of the fumaroles of the Katmai region," Nat. Geog. Soc., Contributed Technical Papers, Katmai Series, No. 2). This series has been continued this year by the appearance, also from the press of the National Geographic Society, of "The origin and mode of emplacement of the great tuff deposit in the Valley of Ten Thousand Smokes," by Clarence N. Fenner.

This paper will be reviewed in its proper place (No. 480 seq.), but it is appropriate to review briefly the progress of the research as a whole.

The two papers taken together have given us a comprehensive survey of the gaseous emanations found in the Valley of Ten Thousand Smokes and the scoriaceous material filling the valley through which they now emerge. The emanations have been found to consist almost altogether of steam (99.5 per cent or more), with small quantities of chemically active gases (HCl, H_2S, HF) and sulphur (chiefly in incrustations) near the probable sources of the sand-flow. It has also been shown that the water supplying the steam fumaroles in the Valley of Ten Thousand Smokes is supplied for the most part from surface drainage, and that the activity of the fumaroles as shown by the volume and temperature of the emanations is gradually diminishing. Nevertheless, most of the fumaroles are from deep-seated sources.

Dr. Fenner has given attention particularly to the character of the sand-flow itself and the manner of its deposition. He has shown conclusively that the great deposit of scoria which now fills the valley can not have been ejected from the Katmai crater. It is overlain by Katmai ash, and, moreover, it is several miles away, with a region containing several glaciers intervening, over which it could not have passed without destroying them and leaving many unmistakable traces. The ash from the volcano shows stratification, while the sand-flow, some hundreds of feet thick in places, shows none. It was free from water and hot enough to reduce to charcoal the trunks of trees embedded in it.

The manner of distribution of the sand and scoria has also been studied in detail and in certain of its phases has been found to compare closely with the nuées ardentes of Mont Pelée, Martinique. It appears to have had many sources through which it reached the surface and to have been highly charged with hot, dry gases at the time of its emergence. There is nowhere evidence that it was a "mud-flow." The manner of forward movement is that of an avalanche of fine sand intimately mixed with dry gases, advancing with great rapidity even over very low grades, as in the case of similar flows at Martinique. Occasional craters, some of considerable size, indicate that the hot flow here and there encountered water, causing secondary explosions.

Dr. Fenner's conclusion, offered for the moment as a working hypothesis pending further investigations which are being conducted on the ground during the present summer, is that a sill, which probably had its origin in the same body of magma which found an outlet at Katmai crater, was driven like a wedge under hydrostatic pressure between nearly horizontal strata of shale and sandstone underlying the valley; that the upheaval produced by the entrance of this sill served to shatter the valley floor throughout its whole extent from the slopes of Mount Trident to the Ukak Outlet. Through this shattered floor the valley drainage has had access to hot magma, and in all probability the magma itself has broken through the floor at Novarupta and perhaps elsewhere. The long life and high temperature of the fumaroles indicate an intrusive mass of considerable volume.

Through the courtesy of the U. S. Geological Survey, Dr. Fenner was enabled to join one of their field parties in Alaska during the present summer, and will no doubt discover further evidence regarding the sand-flow in the Valley of Ten Thousand Smokes and the eruption of Mount Katmai itself, which offers a most interesting and hitherto undiscussed problem.

The unusual number of papers published during the current year by members of the Laboratory staff, which will be reviewed individually in the following pages, precludes further discussion of their more general aspects in this place.

PUBLICATIONS.

(466) Summary of the literature relative to the formation of film on polished glass surfaces. George W. Morey. J. Opt. Soc. Amer., 6, 688–693. 1922.

The stability of polished glass surfaces is of prime importance in the design and manufacture of optical instruments, and all factors affecting their stability are worthy of careful consideration. Some glasses are inherently inferior in their resistance to the corrosive action of water and weak acids; other glasses, possessing a high degree of resistance to such "weathering" action, often give trouble by becoming covered with a coating resembling that produced by the weathering of an inferior glass, but actually due to entirely different causes. This particular type of coating has been called "film," and this report summarizes the information contained in the literature on the formation, appearance, cause, and prevention of film on polished glass surfaces.

(467) The silicates of strontium and barium. Pentti Eskola. Am. J. Sci., 4, 331–375. 1922.

This paper contains investigations of the binary systems $SrO–SiO_2$, $BaO–SiO_2$, $SrO.SiO_2–CaO.SiO_2$, and $BaO.SiO_2–CaO.SiO_2$, and of certain more complicated strontium and barium silicates. For the system $SrO–SiO_2$ there occur the following compounds: SrO, $2SrO.SiO_2$ $SrO.SiO_2$, and SiO_2. The strontium metasilicate, $SrO.SiO_2$, was obtained as crystals which are clearly hemimorphic, apparently hexagonal, but really probably monoclinic. Optically they are closely similar to those of $CaO.SiO_2$ with which they form a continuous series of mix crystals with a minimum in the melting curve. In the system $BaO–SiO_2$ the compounds BaO, $2BaO.SiO_2$, $BaO.SiO_2$, $2BaO.3SiO_2$, $BaO.2SiO_2$, and SiO_2 were found. Of these the dibarium trisilicate, $2BaO.3SiO_2$, and barium disilicate, $BaO.2SiO_2$, showed remarkable behavior, being isomorphous, of orthorhombic symmetry, and forming a complete series of solid solutions without maximum or minimum in the melting diagram. The indices of refraction show continuous though not linear variation with the composition. The barium metasilicate is not isomorphous with calcium and strontium metasilicates, being probably orthorhombic. It forms, with $CaO.SiO_2$, a double compound, $2CaO.BaO.3SiO_2$, which melts incongruently, breaking up into α–$CaO.SiO_2$ and liquid. It is optically uniaxial and negative.

Neither strontium nor barium metasilicate forms, with magnesium metasilicate, a double compound analogous to diopside, $CaO.MgO.2SiO_2$. This is considered as a special case of the more general rule that calcium, in those compounds in which it can be replaced by magnesia and ferrous oxide, can not be replaced by strontia or baryta, while the isomorphous series including strontium or barium compounds may have isomorphous and miscible analogs among sodium, potassium, or lead compounds.

Both strontium and barium form feldspars. The strontium feldspar, $SrO.Al_2O_3.2SiO_2$, has indices of refraction exactly like those of anorthite, and the two seem to be completely miscible. The barium feldspar, $BaO.Al_2O_3.2SiO_2$, is monoclinic and like the natural celsian, which is known to be isomorphous and miscible with orthoclase.

Calcium, having the lowest atomic weight among the so-called alkaline earth elements, forms the basic silicates $3CaO.SiO_2$ and $3CaO.2SiO_2$, the analogs of which were not found among the silicates of strontium or barium.

The last-named silicates, on the other hand, were now found to include the acid silicates, $2BaO.3SiO_2$ and $BaO.2SiO_2$. This is a similar relation to that known for the alkali metals, of which also the one having the lowest atomic weight (lithium) forms the most basic silicates and those with higher atomic weights (potassium, etc.) more acid silicates.

(468) A high-temperature regulator for use with alternating current. Howard S. Roberts. J. Opt. Soc. Amer., 6, 965–977. 1922.

This apparatus is a modification, for use with alternating current, of the author's direct-current furnace temperature regulator (J. Wash. Acad. Sci., 11, 401–409, 1921. Laboratory Publication No. 428). It is intended for use with any sort of electrical heating device whose heating element has a reasonably high temperature coefficient of resistance and is not subject to accidental changes of resistance. Its performance is about the same as that of the direct-current apparatus.

(469) A worked jade pebble from Copan. Henry S. Washington. J. Wash. Acad. Sci., 12, 387–391. 1922.

A jade pebble found by Dr. S. G. Morley during his excavations at the Maya city of Copan is described. The pebble has been perforated to extract disks for the making of ear ornaments and is sawn in two. Microscopic examination shows that the "jade" is composed largely of albite, with less diopside-jadeite. The preponderance of diopside over jadeite, brought out by a chemical analysis, is unique among Middle American jades, with which it is contrasted.

(470) Deccan traps and other plateau basalts. Henry S. Washington. Bull. Geol. Soc. Amer., 33, 765–803. 1922.

In this paper are described the so-called plateau basalts which, in various parts of the earth, have issued from fissures and have covered numerous areas with thick series of horizontal flows, which were evidently of great fluidity. The basalts of the Deccan in India are described in considerable detail on the basis of specimens from all parts of the area. The specimens were furnished the writer by the Geological Survey of India. Of these, 11 new chemical analyses are given. They are shown to be basalts of generally very uniform composition, but are distinguished from most basalts of volcanic cones by their high content in iron oxides and by certain mineralogical peculiarities. The basalt flows of the Columbia and Snake River Valleys in the northwestern corner of the United States (here named the Oregonian region) are also described, along with several new analyses. These basalts are shown to be closely similar in all respects—structurally, mineralogically, and chemically—to those of the Deccan.

The basalts of the so-called Thulean region are also described; this includes the large, now mostly sunken, area of the North Atlantic, represented by Iceland, parts of Scotland and its adjacent islands, East Greenland, Jan Mayan, and Spitzbergen. A number of new analyses of basalts from Iceland and the Faroe Islands are given, and it is shown that in general the Thulean basalts are much like those of the Deccan. The plateau basalts of Siberia, Patagonia, and the Lake Superior and eastern Atlantic regions in the United States are also discussed.

From these abundant data it is shown that the plateau basalts form a type chemically and mineralogically different from the more common basalts that issue from volcanic cones with explosive activity, and the general classification of basalts is briefly discussed. The cause of the great fluidity of these plateau basalts is attributed to their high content in iron oxides.

(472) Temperature changes accompanying isentropic, isenergic, and isenkaumic expansion. Leason H. Adams. J. Wash. Acad. Sci., 12, 407–411. 1922.

When the pressure on a substance is released, the change in temperature depends on the method by which the pressure is dissipated. In this note the three principal types of expansion are compared, and equations and numerical examples are given.

(473) The jades of Middle America. Henry S. Washington. Proc. Nat. Acad. Sci., 11, 319–326. 1922.

In this paper are described the various materials known as jade, of which are made many ancient objects found in Mexico and Central America. The descriptions are based largely on a considerable number of such objects found at Chichen Itzá in Yucatan. It is shown by microscopical and optical examination and by many chemical analyses that these jades form a series of peculiar rocks running from a pure diopside-jadeite to nearly pure albite. A pure diopside-jadeite (called tuxtlite) is best represented by the material of the Tuxtla statuette described in a previous paper ("The jade of the Tuxtla statuette," Proc. U. S. Nat. Mus., vol. 60, art. 14, 1922; see abstract No. 438, Annual Report, 1922). This combination of diopside and jadeite appears to be hitherto unrecognized in mineralogy, and various series of determinations of optical characters and densities are given to show its peculiarities. Also, this peculiar albite-tuxtlite series of rocks seems to have been hitherto overlooked. With scarcely an exception, the Middle American jades belong to it, so that it is characteristic of American material. Minerals of this series seldom or never are found among Chinese or other Asiatic jades, so that it seems clear from the present studies that the provenance of the jade of the ancient Middle American objects is either in Mexico or Central America and that it has not been brought from Asia. The archæological bearings of this are briefly discussed.

(474) On the crystal structure of ammonium chloride. Ralph W. G. Wyckoff. Am. J. Sci., 4, 469–475. 1922.

It is shown that the Laue photographic data obtained from crystals of the low-temperature form of ammonium chloride are in agreement with the powder data in assigning to it a structure containing one chemical molecule within the unit cube. The consequences introduced by the disagreement between the symmetry of this uniquely determined structure and the symmetry as obtained by ordinary crystallographic means are discussed. It is pointed out that it is not permissible to accept etch-figure data and face development as definite indications of the symmetry of the arrangement of the atoms within a crystal.

(476) A theory of the structure and polymorphism of silica. Robert B. Sosman. J. Franklin Inst., 194, 741–764. 1922.

There exists a wide variety of experimental data on the forms of silica, and particularly on quartz, which have never been assembled and explained on the basis of a single consistent set of hypotheses as to the ultimate structure of this substance. This paper attempts to provide such a set of hypotheses, based upon the general knowledge already gained concerning the structure of matter in general and silica in particular.

It is believed that the silica atom-triplet maintains a certain degree of individuality in its amorphous and crystalline states as well as in its compounds, and the freedom of its oxygen atoms to change their positions with respect to the silicons is restricted. The triplets are assumed to assemble into chains or threads in the liquid and glassy states, and a thread structure persists in the crystalline states. The three principal crystalline modifications (cristobalite, tridymite, quartz) are built up by combining the threaded triplets in three different ways, the connection between threads being through the oxygen atoms. The high-low ($\alpha-\beta$) inversions in all the forms are thought to be due to the same underlying mechanism, namely, a change in the state of motion of certain electron orbits, resulting from increased thermal vibration of the atoms, whereby the shape of the silica triplet and the relative positions of the two oxygen atoms are suddenly altered.

The theory as a whole gives a satisfactory explanation for many phenomena of silica not discussed in the paper, and many phenomena not yet tested experimentally are predictable from the theory.

(477) The crystal structure of hydrazine dihydrochloride. Ralph W. G. Wyckoff. Am. J. Sci., 5, 15–22. 1923.

Using Laue photographic and spectrographic data and making use of the results of the theory of space groups, the manner of arrangement of the atoms within the unit cell of a crystal of hydrazine hydrochloride, which contains four chemical molecules and is 7.89 A. U. on a side, has been determined. The parameter v defining the positions of the chlorine atoms is determined as 0.27+ and the most probable value of the nitrogen parameter is estimated as about 0.04. The distance between adjacent chlorine atoms thus is approximately 3.96 A. U.; between chlorine and nitrogen atoms about 3.14 A. U. It is pointed out that these results are greatly at variance with the hypothesis of constant atomic radii.

(478) The genesis of melilite. N. L. Bowen. J. Wash. Acad. Sci., 13, 1–4. 1923.

This paper discusses the conclusions reached by K. H. Scheumann regarding the origin of certain rocks from Polzen, Bohemia. Scheumann applies to these rocks the results of experimental work given by Bowen in connection with the study of alnoites occurring near Montreal. Scheumann concludes that the production of melilite by reaction of augite and nephelite-rich liquid, as advocated by Bowen, is to be regarded as supplemented by actual addition of lime to the magma. It should be noted, however, that if melilite were commonly produced merely by addition of lime to a magma, that mineral should be found as frequently in deep-seated rocks as in surface rocks. The observed absence of melilite in deep-seated rocks therefore points to the dominance of the reaction method of forming it in nature. Scheumann points to the supposed absence of analcite (a product of the above reaction) in melilite rocks, but examination of such rocks reveals two occurrences in which analcite is found, the one at Moiliili, Oahu, Hawaii, and the other at Wolf Kraal House, Namaqualand.

Scheumann's rocks have escaped the attention of many petrologists on account of his use of local names, such as polzenite and modlibovite. Such names, now commonly used by petrologists, are to be deplored, and an appeal is made for the use of names descriptive of the actual mineralogy of the rocks.

(479) Notes on the electric heating of calorimeters. W. P. White. J. Wash. Acad. Sci., 13, 17–28. 1923.

The calorimeter is most accurate when the measurements are comparative. The practical working standard in the best work is nearly always a quantity of heat supplied electrically. To define the calory electrically, therefore, is merely to recognize an existing situation, but should avoid the needless confusion which now often arises from the use of various slightly different calories.

When heat is supplied very uniformly by an electric current, the thermal head of the calorimeter can advantageously be calculated without observing it during the actual heating. An analysis of the errors of this form of procedure is given which shows that it is, if anything, more accurate than when the thermal head is observed. It evidently releases the experimenter's time for more essential observations.

These more numerous observations contribute to precision when the heating current is relatively unsteady. In extreme cases, however, a coulometer is almost unavoidable, probably with some loss of precision compared to the usual method at its best.

The heat conductivity of the leads to the electric heater, and the heat produced in them, may give rise to errors, for whose magnitude approximate formulas are given. The most efficient dimensions for the heater leads vary greatly with the other conditions of the experiment.

(480) The origin and mode of emplacement of the great tuff deposit in the Valley of Ten Thousand Smokes. Clarence N. Fenner. National Geographic Soc., Contributed Technical Papers, Katmai Series, No. 1. 1923. pp. 1–74.

During the period of volcanic activity in the Katmai region in 1912 the floor of the Valley of Ten Thousand Smokes became covered with a deposit of tuff of great thickness, possibly attaining several hundred feet in places. Certain features of this deposit have been described in previous publications, but not in detailed or complete form. As a result of the Katmai Expedition of 1919, certain very definite conclusions regarding its origin were arrived at, and these conclusions and the reasons for them are given in detail in this article. The principal points that seem to be established by the evidence are that Katmai crater could not have been the source of the material, nor could any other single point of extrusion have supplied it all, but that a number of vents (possibly a large number) must have broken out on the floor of the valley, in Katmai Pass, and perhaps on the lower slopes of Mount Trident. Probably the new volcano Novarupta was a principal vent, but others are indicated along the fissures which shatter the floor of the valley and along which the present fumaroles are situated. The material was at a high temperature when extruded. In many respects the form of eruption doubtless resembled very closely the nuées ardentes of the Antillean eruptions of 1902. Certain characteristics of the fissures of the valley area lead to the inference that a sill-like body of magma was driven under the valley floor.

The make-up and general character of the deposit are described. Most of the material is a highly siliceous glass, shattered to a fine dust, or having the form of pumice, but mingled with this is a considerable amount of basic scoria and pumice. To account for the latter, we are led to a study of the material that was explosively ejected from Novarupta after the sand-flow occurred, and of that which forms the dome. This study shows that a large amount of old basic lava became involved in the newly rising siliceous magma at Novarupta and was melted down by it. Similar processes are supposed to have occurred at other vents, and by this melting down and by subsequent inflation the basic pumice and scoria were developed.

A comparison is made with other instances of nuées ardentes, and the characteristics of this form of eruption are discussed.

(481) The crystal structure of the alums. Ralph W. G. Wyckoff. Am. J. Sci., 5, 209–217. 1923.

This paper is a briefer account, in English, of the experiments described in No. 481*a*.

(481*a*) Die Kristallstruktur der Alaune. Ralph W. G. Wyckoff. Z. Kryst., 57, 595–609. 1923.

It is shown that Laue photographic and spectrum photographic studies give T_h^6 rather than the previously assigned T_h^2 as the corresponding space group for the alums. The manner of arrangement of the atoms within the unit cell is outlined, though no attempt is made to locate those atoms having variable parameters. It is pointed out that the 12 water molecules fall into two sets of 6 each. The hydrogen atoms in the ammonium groups of the ammonium alums present an interesting problem in the impossibility of arranging them into a chemically plausible radical which will possess a symmetry in keeping with that of the rest of the crystal.

These spectrographic observations clearly show the practical inability of unaided spectrometer measurements to furnish reliable data for the determination of crystal structures.

(483) On the hypothesis of constant atomic radii. Ralph W. G. Wyckoff. Proc. Nat. Acad. Sci., 9, 33–38. 1923.

It is shown that the existing crystal structure data are not in agreement with the hypothesis of constant atomic radii. They conform, however, to the rule that in isomorphous crystals composed of only two kinds of atoms the interatomic distances have additive properties which can be illustrated through a summing up of "atomic radii." The data also show that for compounds of different crystal structures in which the atomic environments are different the interatomic distances likewise are changed. Where the changes of environment are relatively small, this change in interatomic distance may be almost negligible; in other cases it amounts to several tenths of an Ångstrom unit.

(484) The compressibility of minerals and rocks at high pressures. Leason H. Adams and Erskine D. Williamson. J. Franklin Inst., 195, 475–592. 1923.

This paper concludes the presentation of the results for the compressibility of 40 solids, including 14 minerals and 10 rocks, at hydrostatic pressures up to 12,000 megabars, corresponding to a depth of 40 kilometers below the surface of the earth. The method used was that previously described and shown to yield consistent results.[1] According to this method, the specimen, completely surrounded by a liquid, is subjected to pressure in a thick-walled steel bomb, and the decrease in volume determined by the piston-displacement.

The compressibility of the minerals usually falls off slightly as the pressure is increased. For the less compressible minerals, however, the change in compressibility is so small as to escape detection by the present method, the precision of which corresponds to about 0.01×10^{-6} per megabar, that is, to 1 per cent of the total compressibility of the less compressible minerals. The absolute accuracy, of course, is not so high.

In connection with the compressibility of rocks a complication is introduced by reason of their porosity, which even in the case of igneous rocks is often enough to affect the compressibility. In order to determine the effect of porosity at pressures within the range of experiment—1,000 to 12,000 megabars—the porous rocks were covered with a thin jacket of pure tin, which served to prevent the liquid from entering the pores and thus allowed the closing-in of the pores to contribute to the decrease in volume of the sample as a whole. It was found that at pressures above 2,000 megabars porosity has very little effect on the compressibility; but a comparison with the results of F. D. Adams and E. G. Coker shows that certain rocks, notably the more porous ones, may have at low pressures an abnormally high compressibility.

The results show that, except for very low pressures, the compressibility of a rock may be calculated directly from the known compressibility of the constituent minerals, provided that the rock is holocrystalline. In general, the compressibility decreases with increasing basicity, that is, with decreasing silica-content. Quartz and metallic iron may be considered to stand at the two extremes as regards the compressibility of igneous rocks. In any given class of rocks the variation in compressibility at high pressures is small and almost wholly due to the variation in composition; at low pressures the variation from one rock to another in the same class is much larger and depends mainly on the degree of compactness of the rock. The granites as a rule show at low pressures a compressibility much above what may be called the normal compressibility, but basic rocks may preserve their relatively small normal compressibility down to low pressures. At 10,000 megabars the compressibility of a typical granite is about 1.9×10^{-6} per megabar and that of a typical gabbro is about 1.2×10^{-6}.

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[1] See Annual Report of the Director, 1919; in Year Book No. 18, Carnegie Inst. Wash., p. 160.

From the ratio of the velocities of the two kinds of waves transmitted through the earth and from the known elastic behavior of compact rocks, there is reason to believe that the value of Poisson's ratio for rocks at moderate or high pressures is very close to 0.27. From this value and from the measured compressibility the rigidity of a number of typical rocks is calculated. The rigidity of a typical granite at 10,000 megabars is 0.3×10^6 megabars; that of a typical gabbro is 0.5×10^6; and that of an ultra-basic rock, e. g., a dunite, is 0.6×10^6. The rigidity of the earth as a whole, which is probably near that of steel (0.9×10^6), is higher than the value for the most rigid silicate rock; but doubtless the rigidity of a basic or ultra-basic rock is raised enough by a pressure corresponding to a few hundred miles of rock to yield the required value.

From the values of the bulk modulus (the reciprocal of the compressibility) and of the rigidity the velocities of the two kinds of waves transmitted through the earth are calculated for the various types of rocks. With increasing basicity of the rocks the velocity of the longitudinal vibrations increases steadily from the value for granite, 5.6 km./sec., to that for dunite, 7.4 km./sec., but is lower, 6.0 km./sec., for metallic iron. The initial velocity of the longitudinal vibrations is usually taken to be a little above 7 km./sec. This corresponds to a gabbro or to a pyroxenite, and furnishes an indication of basic or ultra-basic material at a relatively small depth below the surface of the earth.

The bearing of the results for the elastic constants of rocks on the nature of the earth's interior will be discussed further in a subsequent paper.

(485) A chemical study of the fumaroles of the Katmai region. E. T. Allen and E. G. Zies. National Geographic Soc., Contributed Technical Papers, Katmai Series, No. 2. 1923. pp. 75–155.

The material of this publication has been summarized in the annual report for 1922, Carnegie Institution Year Book 21, pp. 128–130.

(486) The geographical study of population groups. M. Aurousseau. Geographical Review, 13, 266–282. 1923.

The different kinds of population groups are briefly described, and the trend of their evolution into the groups of the present day is discussed. The principle is deduced that the character and development of the group are the result of interaction between the group and its region. The historical side of the growth of the group in its region is examined, and it is shown that overpopulation of the region tends to adjust itself by revolutionary change in the method of occupation. The supplanting of ruralism by urbanism at the present time, and the accompanying evolution of the region of simple and uniform production, is believed to have assisted the rise of the conurbations. These in turn have made the world as a whole their region of supply, and foreshadow a period of world overpopulation, which is an extension of the regional overpopulation of past times.

(487) Note on enstatite, hypersthene, and actinolite. H. S. Washington and H. E. Merwin. Am. Mineralogist, 8, 63–67. 1923.

The optical characters and chemical analyses are given of enstatite from Espedal, Norway; hypersthene from Nain, Labrador; and actinolite from Krageroe, Norway. The materials studied were those used by L. H. Adams and E. D. Williamson in their study of the compressibility of minerals and rocks. (See No. 484.)

(488) A survey of existing crystal structure data. Ralph W. G. Wyckoff. J. Franklin Inst., 195, 183–210; 349–365; 531–552 (in 3 parts). 1923.

The existing studies of crystal structure are briefly considered in the light of the results of the theory of space-groups, and a summary given of the results of those determinations which appear from this standpoint to be probably correct.

From this review examples are collected of the insufficiencies of the older methods of study based upon a single diffraction method and not making full use of both available crystallographic information and the results of space-group theory. These illustrations are held to be numerous and striking enough to make indisputably clear the practical necessity of using the more generally applicable methods of investigation now available.

(489) The isomorphism of albite and anorthite. F. Zambonini. (Abstract by H. S. Washington.) Am. Mineralogist, 8, 81–85. 1923.

This is an abstract of a paper by Zambonini (Rend. Accad. Lincei, 31, 295. 1922), in which he suggests that the isomorphism of the feldspars is to be explained by the similar diameters of the mutually replacing atoms, especially silicon and aluminum, sodium and calcium, and potassium and barium. He holds also that equality in the sums of the valencies of the replacing elements is essential. His views are compared with the similar suggestion of E. T. Wherry, who, however, minimizes the importance of equality of the valencies.

(490) On structure and isomorphism in crystals. Ralph W. G. Wyckoff. Am. Mineralogist, 8, 85–92. 1923.

This paper is primarily a discussion from the standpoint of crystal analysis of a recently proposed hypothesis which considers isomorphous replaceability to be essentially conditioned by identity in size of the replacing and replaced atoms. It is pointed out that neither do the atoms in crystals have constant radii nor are crystals closely packed atomic groupings. The connection between isomorphism in crystals and their atomic arrangements is briefly discussed and the absence of a cause-and-effect relation between the two indicated. Further, explanations of isomorphous replacements in terms of "atomic radii" are expressions in other words of the well-known rule of similar molecular volumes. Taking as illustrative the case of the isomorphous mixing of albite and anorthite, some of the conditions which must be fulfilled in such a dual replacement are outlined, but it is emphasized that too little is now known to permit the offering of a satisfactory explanation of even this relatively simple instance.

(491) Petrology of the Hawaiian Islands: I. Kohala and Mauna Kea, Hawaii. Henry S. Washington. Am. J. Sci., 5, 465–502. 1923.

This paper is the first of a projected series of seven which will deal with the petrology of the Hawaiian Islands. The studies are based on the largest collection of Hawaiian rocks that has yet been available; some of them were collected by the author, and many others by other geologists. Especial attention will be paid, throughout the series, to the chemistry of the lavas, and a large number of new chemical analyses will be incorporated. Of these, up to the present, about 50 have been made, and the whole series will contain more than 100. The specific gravities of the rocks will also be investigated systematically and fully.

In the introduction to this first paper some questions of classification (especially of the andesites and basalts) and of nomenclature are discussed. The bulk of the paper deals with the rocks of Kohala and Mauna Kea. The rocks of Kohala, the oldest volcano of the island, are shown to be referable to four quite well-defined types: oligoclase andesite, olivine-oligoclase andesite, feldspar phyric basalt, and aphyric basalt. Their chemical characters are shown by 9 new and 3 old analyses. The rocks of Mauna Kea are more femic than those of Kohala and include: andesine andesite, andesine basalt (two types), labradorite basalt, olivine basalt, and picrite basalt. There are 10 new and 2 old analyses of these. Neither quartz-bearing nor nephelite-bearing lavas are found at either of these two volcanoes.

(492) Augite of the Alban Hills, Italy. H. S. Washington and H. E. Merwin. Am. Mineralogist, 8, 104–110. 1923.

A description of one of the typical augites of the Alban Hills is given, with determinations of its optical characters and a chemical analysis. It is shown that there is considerable variation in the augite of this district. The paper is one of a series in a study of the pyroxene group.

(493) The system, calcium oxide-carbon dioxide. F. Hastings Smyth and Leason H. Adams. J. Am. Chem. Soc., 45, 1167–1184. 1923.

Preliminary to the investigation of the natural conditions which may have produced minerals such as cancrinite, spurrite, the dolomites, or other minerals whose compound molecules appear to contain calcium carbonate as one component, the system calcium oxide-carbon dioxide has been investigated.

For this work a heavy-walled, water-cooled steel cylinder has been constructed, for experimentation up to pressures of about 1,000 megabars. Within this container was placed a platinum-wound resistance furnace which readily gave temperatures of about 1400° C. in the high-pressure range. The pressures in every case were developed by the carbon-dioxide gas which filled the free space within the container. The charges, held in small platinum crucibles, were sufficiently small to insure fairly uniform temperature distribution. Electrical leads for the furnace and for the thermo-elements were brought through the container walls in suitable soapstone plugs.

The eutectic between calcium carbonate and calcium oxide lies at 1240° C ± 1° C., the corresponding pressure being 30,000 mm. ± 300 mm. of mercury. Microscopic examination of this mixture indicates the presence of about equal amounts of oxide and carbonate.

The melting-point of pure carbonate has not been attained, but at 1339° C. and 779,000 mm. pressure, there fuses a mixture of carbonate and oxide containing only about 0.3 per cent of oxide. 1340° must therefore be very close to the true melting-point of the carbonate.

The equation of the curve best representing the experimentally determined dissociation pressures in millimeters, in terms of the absolute temperature from 1 mm. to 30,000 mm. (the eutectic pressure), is found to be

$$\operatorname{Log} p = -11355/T - 5.388 \operatorname{Log} T + 29.119.$$

The values of Log p plotted against $1/T$ do not deviate greatly from the best representative straight line which may be drawn through the points determined by the data up to the eutectic point where fusion takes place. Above this point the pressure rises much more rapidly with the temperature than is indicated by the above equation.

It has been shown also that a transition-point of one form of solid calcium carbonate into another at about 970°, reported first by H. E. Boeke, does not exist. The evidence for this is both thermo-dynamic and directly experimental. The thermo-dynamic evidence is that the pressure-temperature equilibrium curve for this system shows no break until the eutectic point is reached. The experimental evidence is that the most delicate measurements failed to record any heat absorption by calcium carbonate, provided dissociation or fusion were prevented, and that large crystals of calcite show no tendency to fracture or to twinning, when passed repeatedly through the supposed transition temperature.

(494) X-ray diffraction effects from liquids and liquid mixtures. Ralph W. G. Wyckoff. Am. J. Sci., 5, 455–464. 1923.

Photometered results are given of the X-ray diffraction patterns from the following pure liquids and their 1:1 (by volume) mixtures: benzene and carbon tetrachloride, methylene iodide and carbon tetrachloride, glycerol and water. Curves are also given for water and strong aqueous solutions of potassium chloride and iron ammonium alum. These measurements are in agreement with the assumption that the pattern of a liquid mixture is the sum of the diffractions of its component liquids. The various hypotheses concerning the source of the bands in "liquid patterns" are mentioned, and it is pointed out that the present experiments favor an origin within rather than between molecules, but do not exclude the possibility of their arising from characteristic associations of molecules.

(495) The scientist or engineer as reserve officer. F. E. Wright. Army Ordnance, 4, 85–87. 1923.

During the recent war many scientists and engineers entered the Army and were assigned, as officers, to tasks and problems involving research work on subjects more or less connected with their peace-time activities. These men had had little military training, but functioned so successfully as technical experts that on retirement to civil life many were persuaded to enter the Officers Reserve Corps. In order to keep these officers prepared for war duty, training is required, and the question arises what kind of training is best and who is responsible for giving it. An analysis of the situation leads to the conclusion that responsibility rests with the Army to assign its scientist officers to special tasks; to outline for each officer his particular field or group of problems; to keep him in touch with the research problems of his field that are being attacked within the Army; and to stimulate and maintain his interest in the game by requiring of him an annual progress report on some phase of the work in his field. Once the field of his war-time activities has been designated, responsibility rests with the scientist reserve officer himself to survey the field, to keep himself posted on the literature covering this field, to keep track of and to bring into the Officers Reserve Corps the available personnel throughout the country especially suitable to form a nucleus which will be ready to serve in case of war and which in peace-time will continue to carry on and to maintain the section through the passing years.

(496) Preliminary tests of the gases at Sulphur Banks, Hawaii. Eugene T. Allen. Bull. Hawaiian Volcano Obs., 10, 89–92. 1922.

A description of several new methods for the analysis of fumarole gases and their application to the gases of the Sulphur Banks, Hawaii. The work was undertaken for the elucidation of the chemical processes through which the gases are transforming the rock into clay and other products, and also for the purpose of increasing our knowledge of the relations of fumarole gases to the original volcanic gases of the same region. The results follow:

H_2O	96.3
Fixed gases (CO_2, etc.)	3.6
SO_2	.096
S_8	.004
HCl	trace
	100.00

Instead of attempting to determine the amount of each constituent in a measured amount of fumarole gas, the ratios of steam to (1) fixed gases, (2) sulphur vapor, (3) sulphur dioxide were separately determined. The volume of each constituent in the gaseous state at the temperature (and corresponding pressure) of the fumarole gases was then calculated. The temperature and pressure in this case were 95.5° and 646 mm. The steam was always measured as condensed water. The fixed gas was measured by water displacement in an aspirator, while a sample of it was collected by a special tube in the train. The free sulphur was condensed along with the water from which it was later separated by filtration, after which it was dried and weighed. The sulphur dioxide was collected by absorption in caustic soda. It was then oxidized to sulphate by hydrogen peroxide, precipitated as barium sulphate, and weighed. The amount of the precipitate due to free sulphur was of course subtracted. The methods proved practical and the results were very satisfactory.

(497) Cubanite: Identity with chalmersite; magnetic properties. H. E. Merwin, R. H. Lombard, and E. T. Allen. Am. Mineralogist, 8, 135–138. 1923.

Cubanite, as described from such typical localities as southeastern Cuba, also Tunaberg and Kafveltorp in Sweden, is compared with chalmersite from Brazil and Alaska. In all respects in which these minerals have been adequately described they are identical. Cubanite is the older name. Cubanite is unique among known strongly magnetic substances in having only one axis of high magnetic susceptibility.

(498) Petrology of the Hawaiian Islands: II. Hualalai and Mauna Loa. Henry S. Washington. Am. J. Sci., 6, 100–126. 1923.

In this paper, which is a continuation of No. 491, are described the lavas of the two volcanoes, with 17 new analyses. The lavas of Hualalai are basalts of rather uniform character, whereas those of Mauna Loa are referred to three chief types of basalt, labradorite basalt, olivine basalt, and picrite basalt. Most of the modern flows are of the first type, which contains an excess amount of silica. Descriptions of the earliest known flows of Mauna Loa, with 4 analyses by Bailey, are incorporated; these descriptions are taken from an as yet unpublished report by W. O. Clark and F. L. Noble. These earliest lavas belong to the same three types as do the later flows, and they seem to have appeared in quite regular succession.

(499) Methods for distinguishing natural from cultivated pearls. F. E. Wright. J. Wash. Acad. Sci., 13, 282–287. 1923.

In recent years the Japanese have perfected a method of inducing pearl oysters to grow pearls which are spherical in shape and so similar to fine pearls in external appearance that pearl experts have had difficulty in distinguishing between them. The essential difference is that the cultivated pearl contains, as nucleus, a bead of mother-of-pearl on which concentric layers of nacre or pearly substance are deposited, whereas most fine pearls consist of nacre throughout. Methods suitable for detecting the mother-of-pearl nucleus in the cultivated pearl are the following: (*a*) Place the pearl over a narrow aperture, focus on it a strong beam of light through the aperture, and observe the differences in degree of transparency as the pearl is rotated. (*b*) Stand with the back toward a window or other source of light and observe, on rotating the pearl, that in certain positions the characteristic mother-of-pearl sheen is visible, shining out from inside the pearl. (*c*) (Modification of the Galibourg-Ryziger method). Observe with the aid of a microscope the walls of the hole drilled through the pearl as seen reflected by a small bead at the end of a fine gold wire as it moves through the hole. At the boundary between the mother-of-pearl bead and the enveloping nacre substance there is an appreciable change in intensity of illumination which is characteristic of the cultivated pearl.

(500) The residue from silica in rock-analysis. M. Aurousseau. J. Wash. Acad. Sci., 13, 330–332. 1923.

The residue remaining after the driving off of silica by hydrofluoric acid was analyzed and was found to be composed principally of the oxides of titanium, iron, magnesium, and aluminum, with small amounts of lime, phosphoric oxide, and sulphur trioxide. The bearing of these results on rock-analysis is discussed.

(501) A comparison of the heating-curve and quenching methods of melting-point determinations. George W. Morey. J. Wash. Acad. Sci., 13, 326–329. 1923.

The heating-curve method, which is the method followed almost exclusively in the study of metals and of salts which crystallize readily, is compared with the quenching method, used chiefly in the study of substances which are difficult to crystallize, such as most silicates. It is well recognized both in theory and practice that the melting-point of a substance of the latter class is more accurately determinable by the quenching method. Taking the melting-point determination by this method as the standard, it is shown that the true melting-point lies on the more rapidly rising end portion of the heating curve. As usually interpreted, therefore, the heating-curve method tends to give a melting-point which is too low. The difference in the present case (sodium metasilicate) is of the order of magnitude of 2° or less at about 1100°.

(502) Petrology of the Hawaiian Islands: III. Kilauea and general petrology. Henry S. Washington. Am. J. Sci., 6, 338–367. 1923.

In this third installment of the series the lavas of Kilauea are described, with eight new analyses. The ancient lavas differ texturally from the recent ones, but they are all rather uniform in chemical and mineral composition, mostly ordinary basalts, with or without olivine, and fewer picrite basalts. In the second part of the paper the relative ages of the five volcanoes are shown to be: Kohala, Mauna Kea, Hualalai, Kilauea, and Mauna Loa, the last two being thought to be connected. The occurrence of the various types of lava and their succession at the different volcanoes are discussed and the calculated average chemical compositions of the lavas of each volcano are given. The trachytes of Puu Waawaa and Puu Anahulu are thought to be connected with Kohala, not with Hualalai. Daly's views on the origin of the trachytic lavas and of the picrite basalts and the dunitic xenoliths are also discussed.

(504) On the existence of an anomalous reflection of X-rays in Laue photographs of crystals. Ralph W. G. Wyckoff. Am. J. Sci., 6, 277–287. 1923.

Spectrometric and Laue photographic observations by G. L. Clark and W. Duane upon crystals of potassium iodide have been thought to point to the existence of intense diffraction effects which were incapable of explanation on the basis of existing theory. The experiments here described record the inability to find any evidence for these anomalous effects upon numerous

Laue photographs of potassium iodide. Hazy diffraction effects, different from the above, probably related to the familiar "asterism" phenomenon and thus arising from a distortion in the crystalline arrangement, have been observed and briefly described. The data from the Laue photographs are in complete accord with the previously assigned "sodium chloride arrangement" of the atoms in crystals of potassium iodide.

(504*a*) On the existence of an anomalous reflection of X-rays in Laue photographs. Ralph W. G. Wyckoff. Science, 58, 52–53. 1923.

This is an abbreviated account, without any data, of results of the experiments described in the preceding paper.

(505) Comagmatic regions and the Wegener hypothesis. Henry S. Washington. J. Wash. Acad. Sci., 13, 339–347. 1923.

The paper is a brief attempt to apply a petrographic test to Wegener's hypothesis that the two continents of North and South America were formerly united to those of Europe and Africa and that they split and began to separate about late Cretaceous time, the two Americas sliding, upon a semi-solid basaltic substratum, westward to their present positions. If this were true, we should find many correspondences on both sides of the Atlantic between areas of similar deep-seated igneous rocks (comagmatic regions), so that these would correspond if the parts were fitted together again, in their supposed original positions, just like the color areas in a jig-saw puzzle.

The matter is discussed with considerable petrographic detail, into which it is not necessary to go here. It is shown that the characteristic igneous areas of the west coast of Norway have no corresponding areas on the east coast of Greenland, and vice versa. The large area of basaltic lava flows that formerly covered the whole of the North Atlantic between Greenland and the Faroes and Franz Josef Land is held to be an entirely independent incident in the earth's history, analogous to the vast areas of basalt flows in the Oregon region, India, Siberia, South Africa, Patagonia, and elsewhere. Similar correlations are made between the comagmatic regions of igneous rocks of Great Britain and those of Labrador and New England, the rocks of France and Portugal and those of the Appalachian region, the rocks of the north coast of the Gulf of Guinea and those of the Guianas and northern Brazil, and the rocks of the southern west coast of Africa and those of the east coast of South America (eastern Brazil and Argentina).

Although there are a few minor correspondences, the discrepancies are far more numerous and are of major size and importance. The conclusion is drawn that the evidence of comagmatic regions is adverse to Wegener's hypothesis. Wegener's view that the volcanic islands of the Pacific Ocean are fragments of a broken, largely granitic crust covered by later lava flows is disproved by the total absence of inclusions of granitic, metamorphic, or sedimentary rocks in their lavas.

(506) The fusion of sedimentary rocks in drill-holes. N. L. Bowen and M. Aurousseau. Bull. Geol. Soc. Amer., 34, 431–448. 1923.

When a core sample of the beds penetrated is taken during the drilling of an oil well, it is found under some conditions that part of the core consists of a slag-like mass bearing some resemblance to a natural lava. This slag has been pronounced by some geologists to be the result of fusion of rock in the drill-hole as a result of the heat of friction, though some operators have been unwilling to accept this conclusion. The examination of two drill-cores sent us by Professor Bailey Willis, in one of which the beds immediately above the slag were well preserved, has confirmed the opinion that the slag is the result of fusion of the sedimentary rock in place. Chemical analyses of it and the slag show that they are practically identical in composition, except that the fused part or slag has lost nearly all its water, all its CO_2, and about one-half its sulphur, and has received a considerable contribution of iron from the drill-pipe.

Thermal tests in the laboratory show that a temperature nearly if not quite as high as 1150° C. is necessary to produce the results actually obtained in drilling. A metallographic study of the steel shows that the temperature attained was 1050° C. or higher.

The chemical composition and the microscopic characters of the material fused show that it was of the nature of an arkose, a variety of sedimentary rock which appears to be particularly susceptible to such fusion. Since the rock was an arkose, the slag shows only a moderate departure in composition from an igneous rock, but the difference is none the less real, and is in the same direction as that exhibited by typical shales. On account of the arkosic nature of the sediment, the general chemical similarity of the slag and igneous material can not be regarded as affording any support to the theory that igneous rocks are formed by the fusion of shale, nor do the thermal results favor the view that remelting of shale could occur at moderate depths in the earth's crust (say 6 to 10 miles) unless the normal temperatures prevailing at such depths are notably augmented by intrusion of igneous matter from greater depths.

(507) The formation of interference figures. A study of the phenomena exhibited by transparent inactive crystal plates in convergent polarized light. F. E. Wright. J. Opt. Soc. Amer., 7, 779–817. 1923.

Of the many phenomena observed by the student of crystal optics, the most impressive are interference figures. Experience has proved that in order for him to grasp the special relations involved and to maintain a clear picture of them, it is advisable for him to adhere to a single surface of reference and to derive from it the several relations presented by crystals in polarized light. For the petrologist whose work is with thin sections of rocks, and who is therefore chiefly interested in refractive indices and wave normals and not in ray directions, the index ellipsoid is the simplest surface of reference. With the aid of the curves of intersection of the index ellipsoid and concentric spheres the standard equations required by the petrologist can be derived more easily than by other methods. Moreover, the spacial relations are clearly represented graphically by these curves and others derived from them. Thus the *equivibration curves* give the positions in space of all vibration directions of given length; the *equirefringence curves*, the positions of all wave normal directions of given refringence; the *equibirefringence curves*, the positions of all directions of wave normal propagation of given birefringence. For a given crystal plate it is possible with the aid of the orthographic projection of the equirefringence curves to ascertain the positions of the zero isogyres in the interference figure exhibited by the plate. This was first shown by F. Becke, who named the orthographic projection curves skiodromes. With the aid of the equibirefringence curves the isochromatic curves of the interference figure can be derived graphically. For the student thus to ascertain graphically the positions of the isogyres and the isochromatic curves of the interference figure of a given crystal plate of definite thickness and optical orientation is highly desirable because it affords him an insight into the phenomena presented by crystal plates under the petrographic microscope. These conceptions have proved useful in a critical study of the methods which have been proposed by Professor Becke and by the writer for the measurement of the optic axial angle when only one optic axis is in the field of view. The results of this study show that neither method is theoretically correct; that of Professor Becke, because it neglects the rotation of the plane of vibration of transmitted plane-polarized light waves at all boundary surfaces both of crystal plate and of microscope lens system; that of the writer because of similar neglect of the rotation of the vibration plane by the lens system. It shows, furthermore, that because of this rotation a theoretically correct method is not possible. For practical purposes both methods furnish results of about the same order of accuracy.

(508) On the nomenclature of the point groups. Ralph W. G. Wyckoff. Am. J. Sci., 6, 288–290. 1923.

The desirability of changing the prevailing point- and space-group nomenclature is mentioned and a system proposed which is a modification of that of Hilton.

(509) Stone adzes of Egypt and Hawaii. Henry S. Washington. J. Wash. Acad. Sci., 13, 377–383. 1923.

The attention of anthropologists is called to the remarkable similarity in form between the stone adzes used, about 2500 B. C., to excavate (out of limestone) the tomb-chambers at Beni Hassan, on the east bank of the Nile, and those used by the Hawaiians, as late as 1864, for felling trees and shaping wooden canoes and idols. The Egyptian adzes are made of a hard, dense siliceous limestone, composed of secondary silica and calcite in about equal amounts, whereas the Hawaiian adzes are made of a very dense, fine-grained basalt, which occurs at only a few places on the islands. The resemblances consist in the general size and shape of the tool, the curvatures of the faces that make the cutting edge, and the angle of this. Although it is possible that the Polynesian form was derived from the Egyptian through ancient lines of trade, yet the writer believes that the two were of independent origin and arose from similar solutions of similar problems.

(510) Petrology of the Hawaiian Islands: IV. The formation of aa and pahoehoe. Henry S. Washington. Am. J. Sci., 6, 409–423. 1923.

The two most common types of basaltic lavas at the Hawaiian and many other volcanoes are usually called by their Hawaiian names, "aa" and "pahoehoe." The former, also called "block lava," forms long, thick flows, with extremely rough surfaces made up of very irregular, jagged blocks, with more solid rock below. Pahoehoe is a "ropy lava," usually in shorter and thinner flows, formed of coils, festoons, ropes, and lobes, with smooth, glistening surfaces. Internally, aa contains rather few but large and irregular gas-vesicles, whereas pahoehoe has very numerous, small, and mostly spherical vesicles, uniformly distributed. The cause of these differences has for long been in doubt, and this paper records an attempt to solve the problem through chemical analyses and study of thin sections of many Hawaiian basalts.

Analyses show that the two types are chemically identical, except that the ratio of ferrous to ferric oxide is slightly greater in pahoehoe than in aa. As the microscopic study shows that pahoehoe is always more glassy than aa, this difference in the iron oxides is connected with the general rule that the more glassy the texture of a lava the higher the ratio of ferrous to ferric oxide, the chemical composition being otherwise the same; so that this chemical difference has nothing to do with the physical differences. The general explanation of the differences between the two types is as follows.

Pahoehoe lava issues at a higher temperature than aa and has lost much of its magmatic gas by simmering in the throat of the volcano; it also contains very few or no crystals when it reaches the surface. As it contains little gas, the presence of which in solution would increase the fluidity, pahoehoe is rather viscous and solidifies rapidly, although it remains for some time sufficiently liquid or semi-liquid to permit of slow movement of the mass as a flow. The crystallization, which begins soon after extrusion, is soon brought to an end by the rapidly increasing viscosity, so that much, or the greater part, of the lava solidifies as glass. As there are few crystals to serve as nuclei for its escape, the magmatic gas still present is driven out of solution by the increasing viscosity very uniformly throughout the mass and, the greater part being unable to escape, forms the numerous small, spherical bubbles.

Aa lava, on the other hand, issues at a probably lower temperature than pahoehoe and contains much magmatic gas in solution. This dissolved gas renders the lava very fluid, so that crystallization is easy and rapid. The crystallization maintains the gas pressure and gas content of the continuously diminishing, still liquid portion, which thus remains constantly very fluid, so that crystallization is continuous up to, or nearly up to, the point of complete solidification. The fluidity of the liquid portion is further maintained, and crystallization is promoted, by the fact that, in basalts, the feldspars tend to crystallize earlier than the pyroxenes, so that the liquid becomes progressively more femic and therefore more fluid, thus tending to compensate for diminishing temperature. The latent heat given out by the crystallization also tends to maintain the temperature. As there are many crystals to act as collecting nuclei for the magmatic gas that is driven out of solution, large bubbles are formed by coalescence, which rapidly rise through the fluid mass, producing the abundant clouds of steam and gas that accompany aa flows and also freeing from bubbles the lower portions of the flow. Because of the greater fluidity of the liquid portion, aa lava is, in general, able to flow for a longer distance and more rapidly than pahoehoe.

(511) Die Krystallstruktur des metallischen Iridiums. Ralph W. G. Wyckoff. Z. Kryst., 59, 55–61. 1923.

The face-centered cubic arrangement previously assigned to metallic iridium is confirmed and a more accurate method is outlined for determining the fundamental dimensions of a crystal by powder photography. This procedure involves a mixing of sodium chloride, or other standard comparison material, directly with the substance under investigation. Its application to iridium of the highest purity yields a length of side of the unit cube: $a = 3.823$ A. U.

DEPARTMENT OF HISTORICAL RESEARCH.[1]

J. Franklin Jameson, Director.

The following report, the eighteenth annual report submitted by the present Director, covers the period of twelve months extending from September 1, 1922, to August 31, 1923. In the staff of the Department no changes have occurred during the year. Mr. Leland has been in Paris throughout the twelve months, with three brief exceptions. One consisted in a visit to the Archives of the Compagnie des Indes at Lorient, the object of which is described later in this report. The second was a brief period spent in Brussels, in order to attend, in the interest of the Department and as representative of the Institution, the Fifth International Congress of Historical Studies, held in that city on April 8 to 15. The third was a visit of a few days spent in London to attend, in July, on behalf of the Department, the Anglo-American Conference of Professors of History, of whose "continuation committee" he is a member. Miss Davenport had leave of absence from the Institution for the three months extending from March to June, and spent that period at Mount Holyoke College, taking the place of an absent professor.

Several persons outside the regular staff of the Department have during the year given valuable assistance to its work. Professor John S. Bassett, of Smith College, continued throughout the year his editorial work upon the Correspondence of Andrew Jackson, working in Northampton and devoting to the subject as much time as his academic duties allowed. Professor Marcus W. Jernegan, of the University of Chicago, and Miss Elizabeth Waterston, of that institution, working under his direction, spent considerable time in the elaboration of those maps which are to illustrate educational and religious history in the *Atlas of the Historical Geography of the United States*, which is going forward under the general direction of Dr. Paullin. Miss Elizabeth Donnan, formerly a member of the Department, now an associate professor in Wellesley College, devoted most of her summer vacation and some lesser fragments of the year to our work. Mrs. N. M. Miller Surrey and Mrs. R. C. H. Catterall, both of New York City, worked consecutively upon their portions of our work during most of the twelve months.

Others outside the regular staff who assisted in the work of the Department during the year were Mr. David M. Matteson, of Cambridge; Mr. Abel Doysié, of Paris; Miss Ruth A. Fisher, Miss Lillian M. Penson, Miss Isobel D. Thornley, and Miss B. Eliott Lockhart, of London.

As in previous years, acknowledgment is cordially made of the favors constantly shown to the Department, with the greatest liberality, by the officials of the Library of Congress, and especially by Dr. Herbert Putnam, the librarian; by Mr. A. P. C. Griffin, chief assistant librarian; by Mr. Charles Moore, chief of the Division of Manuscripts; and by Mr. P. Lee Phillips, chief of the Division of Maps. Grateful recognition is also made of the courtesy shown by the New York Public Library in facilitating the work of Mrs. Surrey; by the library of Harvard University in aiding that of Miss Donnan and Miss Davenport; by the Association of the Bar of New York City in affording to Mrs. Catterall special opportunities for her work; by the authorities of the British Museum and the Public Record Office in aiding that of Miss Fisher, Miss Penson, and Miss Thornley, and by librarians and archivists in Paris, especially Mr. W. Dawson Johnston, librarian of the American Library in Paris.

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[1] Address; No. 1140 Woodward Building, Washington, D. C.

REPORTS, AIDS, AND GUIDES.

The *Guide to Materials for American History in Paris Archives and Libraries,* upon which Mr. Leland has long been engaged, was advanced during the year in two ways. Both related chiefly to materials in the libraries, which will form the subject-matter of the first of the three volumes contemplated, the second and third being concerned with the materials in the Archives Nationales and the archives of the various ministries or departments of the French government. Of the two lines of work indicated, one has consisted in the editing of notes already taken—verifying names, establishing dates, determining whether documents have been published or used, and reducing the original notes to final, and when possible briefer, form. The second line of work has consisted in the examining of manuscripts not previously inspected, as, for instance, the examination of those which have come into the Bibliothèque Nationale since the work was begun in 1907, or since it was interrupted by the advent of war in 1914. Mr. Leland in his reports makes special mention of documents of 1565 relating to the Florida expedition of Ribault, of a large amount of material relating to companies of commerce of the seventeenth century, of a long and important series of letters, chiefly from the ports, to Cabart de Villermont, and running from 1680 to 1706, in which are many letters relating to America. With Mr. Doysié's assistance he has also completed the examination of the Colbert manuscripts.

All the work of the year has been done in the Bibliothèque Nationale, except an examination in September of the archives of the Compagnie des Indes at Lorient. In general, the plan of the volumes on which he is engaged confines his work strictly to Paris, but these archives at Lorient are, for the period of the eighteenth century, so closely related to those of the Ministry of the Marine in Paris that it seemed inappropriate to leave them out of his survey, more especially as they had been lately reputed to be of importance to the history of Louisiana. The actual amount of interest of their American contents proves to be less than had been supposed, but they contain some useful materials, and these were fully examined and noted.

The work upon which Mrs. Surrey has been engaged, the making of a calendar of documents in Paris archives relating to the history of the Mississippi Valley, is in practice an adjunct of Mr. Leland's and Mr. Doysié's work just reported upon, though it has a separate history and origin, which have been described in previous reports. From the beginning of September to the end of December she was at work in Paris making that portion of her calendar which refers to the numerous papers relating to Louisiana and other parts of the Mississippi Valley contained in Series B of the Archives des Colonies. This involved the thorough examination of several hundred volumes of manuscripts. From January to the end of June she was at work in New York, revising and adding to the calendar, putting the cards into chronological order, preparing the index of the names, and performing like tasks. The arranging in chronological order resulted in the consolidation of duplicate entries to such an extent as to reduce the total number of cards by more than 2,000, since many documents, chiefly those having the nature of laws, decrees, and orders, have been found to exist in from two to twenty duplicates. This consolidation usually makes it possible to detect the original and to place the copies in their proper status. The last part of Mrs. Surrey's work consisted in the calendaring of documents read by means of transcripts recently acquired by the Library of Congress.

It was stated in last year's report, in a passage referring to the Public Record Office of Ireland, and to Professor Bell's report of materials relating to American history which he found in that repository, that while the buildings in which the Irish archives were preserved had been almost completely destroyed during an insurrection, the destruction of the contents was understood not to be complete. Subsequent information has shown that, so far as the papers examined by Professor Bell are concerned, the destruction was absolute. None of these papers remain, and there will be no thought of publishing the notes formerly obtained.

Mr. van Laer has not yet been able to prepare for publication the manuscript of his report on the numerous and important materials for American history in the Dutch archives, but in a conference toward the end of the year plans were made which it is hoped may bring about this result before long.

Aside from the Dutch and French archives, the only national archives in Europe having much importance for American history and yet remaining to be examined and reported upon in our series of Guides are the archives of the Scandinavian countries. Their importance consists in three particulars. First, the Swedish archives contain copious materials regarding the history of the early settlements on the Delaware River in the region called New Sweden, of the Swedish West Indies, and of the Swedish West India Company, while the Danish archives contain records of the Danish West Indies, not only those which have always been in the royal archives, but also those which were formerly preserved at the capital of the islands, Charlotte Amalie, whence they were transferred to Copenhagen several years before the cession of the Virgin Islands to the United States. Secondly, the archives of the ministries of foreign affairs in Stockholm and Copenhagen contain materials for the history of diplomatic relations between the United States and Sweden and Denmark, respectively, complementary to those preserved in the Department of State at Washington. Thirdly, the archives of Sweden, Denmark, and Norway contain materials illustrative of the history of Scandinavian emigration to the United States; these, in view of the great volume of that emigration, are in some respects to be deemed most important of all those that have been named.

The Department has not had the means requisite for a wholly independent examination of all these materials on the same plan of procedure as that followed, in the years before the war, in its examinations of foreign archives. A plan has, however, been devised by which, through combinations with various other means, a volume on the Scandinavian archives can be prepared which will not be seriously different in character from our previous Guides, and which will cover those archives with similar thoroughness. Professor Amandus Johnson, of the University of Pennsylvania, whose admirable work on *The Swedish Settlements on the Delaware, 1638–1664*, has been recognized as the standard authority on the subject ever since its publication a dozen years ago, inserted in that volume an elaborate account of the materials in Swedish archives relating to the subject, so far as this earlier period is concerned. Combining with this his notes of the later materials, and of whatever has been more recently discovered for the earlier period, he has been so good as to permit that, in the proposed volume, the Department may print his full account of all these archival materials for New Sweden. Nothing could better cover this portion of the plan. With similar kindness

Professor Waldemar Westergaard, of Pomona College, author of the standard work on *The Danish West Indies under Company Rule, 1671–1754* (1917), has permitted the Department to reproduce from that volume, now out of print, his full account of the materials on the history of these islands preserved in the archives of Copenhagen, and has made arrangements with competent persons there to continue the data down to later periods of Danish rule.

The Department is also indebted to Professor Westergaard for arrangements made with respect to the papers concerning diplomatic negotiations of the United States with Sweden and Denmark. During residence this year in Stockholm and Copenhagen he obtained through the aid of Mr. Erik Naumann, one of the archivists of the Riksarkiv of Sweden, an adequate account of the diplomatic papers of that government concerning America, and a similar report from the Danish ministry of foreign affairs is to be obtained through the kind offices of Madame Backer.

For the third sort of archival material, that relating to emigration to America from the three Scandinavian countries, the Department has been able to avail itself of means provided through the public-spirited action of the American-Scandinavian Foundation and of its secretary, Mr. James Creese. In the annual assignment, in the spring, of its fellowships intended to promote study in Scandinavia on the part of American students, the American-Scandinavian Foundation awarded one, for the year beginning July 1, 1923, to Mr. Gunnar J. Malmin, of Luther College and of St. Paul, with the understanding that his studies, through all such portion of the year as might be necessary, should be devoted to the making of a detailed report, for this Department and under instructions from it, upon the records of emigration to the United States which might be found in the archives of Sweden, Norway, and Denmark. With grateful appreciation, the Director prepared the necessary instructions, and Mr. Malmin sailed for Norway in July. Before the end of August he had taken at Christiania the necessary notes of materials of the Social Department, which since 1913 has had the control and supervision of emigration, but whose papers on the subject begin in 1845. He has also investigated the material in the departments of foreign affairs, justice, and police, and the Stiftsarkiv (ecclesiastical archives). In these searches he has been very kindly assisted by Mr. Christian Brinchmann, archivist in the Riksarkiv, and by Mr. Th. G. Thorsen, of the Social Department.

In order to make an adequate presentation of the manuscript matter concerning emigration, it will be necessary for Mr. Malmin not to confine his work in Norway to Christiania, but also to make some investigations at the chief other out-ports of emigration, Trondhjem, Bergen, Stavanger, and Christiansand. Similarly, in Sweden, it will be necessary for him to make some inspection of the archives of Gothenburg as well as of the national deposits at Stockholm. The main portion of his report from Christiania is already in hand.

The Department's Guide for the Scandinavian archives will thus be a composite volume, but it is believed that it will embrace all that is essential for the uses of the historical student.

It remains to speak of the archives of the British West Indies. Search of the island archives themselves has not yet become practicable, for want of appropriations, except that, as heretofore mentioned, the Department has already excellent reports on those of Bermuda, the Bahamas, and Jamaica. As has been explained in previous reports, the many volumes in the West Indian section of the Colonial Office Papers, preserved in the Public Record Office in London, are the indispensable complement to the various series which are preserved in the island archives. The examination of these West Indian "classes" of the Colonial Office Papers, by Professor Herbert C. Bell, down to the year 1775, and the receipt of his inventory of American papers thereupon, have already been reported. During the past year Miss Lillian M. Penson, of London, proceeding on lines laid down by Mr. Bell, has continued this survey, from 1775 to 1815, the point at which the inventory is to conclude. What now remains for the completion of the book is the examination of the archives of those of the Lesser Antilles which are colonies of Great Britain.

In the work upon the *Atlas of the Historical Geography of the United States,* Dr. Paullin has during the year completed a considerable number of maps, lying in four different divisions of the work. In the portion relating to economic history, he has finished a map showing incidence of income taxes in 1866, one showing taxes on incomes and profits in 1920, and fourteen showing imports and exports in various periods. In the group of maps relating to the development of geographical knowledge of the country, he has finished the map showing Spanish explorations in the western portions of the United States in the sixteenth and seventeenth centuries, and that showing French explorations in the same region, chiefly in the eighteenth century. He has completed maps showing Indian reservations as they stood in 1840, 1875, and 1920, and one showing Indian tribes and linguistic stocks. Fourthly, he has finished the map showing Indian battles and battles between the English and the French in the period before the Revolution. For all maps that have been completed, the letterpress has also been prepared. In the execution of the maps, Dr. Paullin has had, as usual, the aid of Mr. J. B. Bronson as draftsman. Professor Herbert E. Bolton, of the University of California, gave valuable advice respecting the maps showing French and Spanish explorations in the far West. Preliminary maps for battles of the Revolution and the War of 1812 have also been prepared.

Just before the end of the year reported upon, the Department received from Mr. David M. Matteson, of Cambridge, the completed manuscript of the volume with which he has been occupied on behalf of the Department. This is a compilation of the information respecting manuscripts relating to American history which can be obtained from the printed catalogues of manuscripts put forth by European libraries or from other printed lists which describe manuscripts contained in public repositories. It should be observed that the manuscripts concerning American history which are to be found in the libraries of London, Oxford, and Cambridge have been catalogued in Andrews and Davenport's *Guide to the Materials for American History in the British Museum,* etc., and in others of the Department's British Guides; that the manuscripts in Roman libraries, as well as in Roman archives, were included in the scope of Professor Fish's *Guide to the Materials for American History in Roman and other Italian Archives;* and that the libraries of Paris are included in Mr. Leland's survey already described. Outside these five cities, however, there are in the other libraries of Europe, scattered in small quantities here and there, a large number of manuscripts relating to American history.

Though it is impossible to contemplate the great labor and expenditure involved in a thoroughgoing search for all these, so many catalogues and lists of them have been printed, by European libraries and others, that a large advance toward knowledge of them could be obtained by combining all the data found in such printed accounts.

Mr. Matteson's work has consisted in drawing off from such printed catalogues or lists those items which indicate or describe manuscripts relating to American history. The work has been carried out with great thoroughness in the library of Harvard University, the Boston Public Library, that of the Massachusetts Historical Society, that of Yale University, the New York Public Library, that of Columbia University, and the Library of Congress, and with full and careful use of all the catalogues which they contain, either as separate publications or in bibliographical journals or elsewhere. The result is a collection which will apparently make about 200 pages of print, and lists some 2,000 different manuscripts. The titles and descriptions of these have simply been drawn off from the catalogues as they stand, their verification or further elaboration being out of the question without prohibitive expense; but inasmuch as nearly all these manuscripts are quite unknown to American historical students, it is believed that the manual will be considered a valuable addition to their means of research.

TEXTUAL PUBLICATIONS OF DOCUMENTS.

From the beginning of October to the end of the year reported upon, with the exception of the months already mentioned as spent in the service of Mount Holyoke College, Miss Davenport has worked in Washington or in the Harvard College library upon the second volume of her *European Treaties bearing on the History of the United States.* Five treaties have been completed, extending the work to the Treaty of Ryswick, 1697.

Progress of Dr. Burnett's *Letters of Members of the Continental Congress* has been marked by the publication, in May, of his second volume. It runs from July 5, 1776, to the end of the year 1777, and contains, besides the 795 letters, or parts of letters or diaries, mentioned in the report last year, a preface interpreting portions of the documentary material and making sensible additions to our understanding of the actions of the Congress, and a detailed record of the elections to membership in the Congress by the various States, and of the dates of attendance of the individual members. One-third of the letters dating from the second half of 1776 are not found elsewhere in print; more than half of the letters bearing dates in 1777 are now printed for the first time. The contribution of new information made by this volume is therefore much greater than that in its predecessor, since the period from the opening of the Congress to July 4, 1776, has always received an exceptional amount of attention, while the doings of the Congress in later periods—and subsequent volumes will show this increasingly—have thus far been much less thoroughly made known, and call for much fuller illumination from letters of the members. The present volume casts an especial amount of light on the problems of army organization, military supply, plans for executive departments, finance, and especially the formation of the Articles of Confederation. Dr. Burnett has also advanced largely during the year the preparation of his careful annotations to the text, already prepared, of his third volume.

The first of the volumes of the *Proceedings and Debates of the British Parliaments respecting North America*, edited by Dr. Stock, has been completed during the year, and sent to the press in June. This involved the finishing of the notes of proceedings of the Parliaments and Conventions of the Estates of Scotland, and of the Parliaments of Ireland, down to the year 1689, the writing of the preface or introduction, and the final preparation for print. The volume runs from the first mention of America in the Journal of the House of Lords, in 1542, and of the Commons, in 1549, to the date of the Revolution of 1689, which marks an obvious era in colonial history. It contains all records of proceedings to be found in the Journals and all notes of debates which it has been found possible to obtain from printed books, or from manuscripts in England relating to America or to connections or commerce therewith. At the conclusion of the year, 33 galleys of this first volume have been received from the printer, and read. Meantime Dr. Stock has proceeded with the second volume. Its texts have long been ready; its annotation has been completed up to 1692.

Miss Donnan, whose duties as an associate professor in Wellesley College leave her but a minor portion of time available for the completion of the work on which she was engaged when she resigned from the staff of the Institution, has devoted most of the summer vacation, and some lesser portions of the preceding academic year, to the preparation of her volumes of documents illustrative of the history of the African slave trade to the United States. In September and during the Christmas vacation she secured, by the kindness of the Newport Historical Society, a large addition to her Rhode Island material. Most of the work of the summer has consisted in combining this with other Rhode Island material already obtained and in annotating that section of the book, with some similar additional work for the portion relating to South Carolina. Other work has been carried on in the admiralty papers in the State House at Providence, and at the Essex Institute at Salem. Some additional transcripts from the papers of the Royal African Company in London have been received from Miss Fisher, and some from the French archives, relating to Louisiana, from Mr. Doysié.

The work of Mrs. Catterall, in drawing off materials respecting the history of slavery from the judicial reports of the American States, has during the year been carried through the reports covering Delaware and Missouri, and a portion of the federal cases, and has included the preparation of the introductions to the sections on the Maryland and the English cases, as well as those for Delaware and Missouri. These introductions are intended to exhibit the development of judicial opinion in each State.

The text for the volumes of the *Correspondence of Andrew Jackson*, assumed a year ago to be completed, has received during the year some small additions, chiefly from the Department of History and Archives in the State of Mississippi, the latter having been obtained through the kindness of Dr. Dunbar Rowland, director of that department. The chief progress of the year has consisted in the advancement, nearly to completion, of the work of annotation, upon which Professor Bassett, the editor of the series, has spent as much time as his duties in Smith College and in the University of Chicago would permit.

Advancement of the series of volumes of the *Correspondence of the British Ministers to the United States* during the year has consisted chiefly in the receipt of transcripts from the Public Record Office, furnished by Miss Fisher, extending the series of despatches received by the Foreign Secretary from the British Minister in Philadelphia some four or five years, namely, from the arrival of Robert Liston as minister, in May 1796, to the end of the year 1800, when he returned to England. Transcripts completing the minor series from Nova Scotia have also been received. The Department has now continuous materials for two or three volumes of the series, but in the work of annotating and otherwise preparing these interesting letters for the press, a labor which falls to the Director of the Department, he has been able to make little progress during the year, because of the pressure of other duties belonging to his office.

The first volume of the four devoted to *Historical Documents relating to New Mexico, Nueva Vizcaya, and the Approaches Thereto*, collected by the late Dr. Adolph F. Bandelier and Mrs. Bandelier, and edited by Professor Charles W. Hackett, of the University of Texas, was described, as manuscript, in the last report. The manuscript was sent to the printer in January. At the end of the year the proof-reading was completed, with the single exception of the reading of page-proof of the index, which no doubt will shortly be received. The book will then be published, as a volume of about 500 pages, the Spanish of the original documents on the left-hand pages, their English translations on the right, with careful introductions and annotations. In general terms, this volume, conveying a wealth of new information, extends to the definitive founding of New Mexico and to the year 1609.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the *American Historical Review* has been carried on in the office of the Department and by its staff, mainly by the Director and Miss Griffin, with aid from Dr. Burnett in one section. Various help has been given to the American Historical Association and other historical societies, especially in respect to investigations in Washington archives, and many inquiries from historical students have been answered or transcripts of documents procured for them.

The Director has served as one of the two representatives of the American Historical Association in the American Council of Learned Societies, and as chairman of its committee on a proposed Dictionary of American Biography, similar in design to the British *Dictionary of National Biography.* Mr. Leland, as a member of an American committee, rendered important aid in the organization of the Fifth International Congress of Historical Studies, held in Brussels in April; and in its section on the documentation of the World War, over one of whose sessions he presided, he read a paper on war archives of the United States. He has by invitation attended sessions, and assisted in the work, of one of the subcommittees in the Committee on Intellectual Cooperation organized by the League of Nations. He has prepared an historical account of the work of the National Board for Historical Studies, an organization in whose work during war time the Department was deeply engaged, for the Annual Report of the American Historical Association, and has continued to direct the work of transcribing documents in Paris archives for the Library of Congress. Dr. Stock has given a course of historical instruction in the Catholic University of America, and a course of lectures at the Catholic Summer School of America at Cliff Haven, New York, on the relations between the United States and the States of the Church.

DEPARTMENT OF MARINE BIOLOGY.[1]

In accordance with authority received from the Board of Trustees of the Institution, special investigations at the Tortugas Laboratory have been continued, reports of which will be found in the following pages. Mr. John W. Mills, chief engineer, has remained in charge of all equipment and has superintended necessary repairs to the Laboratory buildings; he also aided in collecting material for laboratory study and in procuring supplies. A bronze tablet, executed by Mrs. Alfred G. Mayor, was erected to the memory of Dr. Mayor on the site of his former activities.

The following investigators studied under the auspices of the Department during the past year:

Dr. Paul Bartsch, Porto Rico, Bahamas, and Tortugas, May and August. Continuation of experiments with cerions.
Dr. H. E. Crampton, island of Moorea, South Pacific. Field investigations on the variation, distribution, and evolution of species of the genus *Partula*.
Dr. C. B. Lipman. Study of sea-water of the Pacific Ocean.
Dr. William H. Longley, Tortugas, June 6 to August 25. Submarine color photography and habits of Tortugas fishes.
Dr. Asa A. Schaeffer, Tortugas, June 6 to July 15. Marine amebas.
Dr. D. H. Tennent, Misaki Laboratory, Japan, May to September. Continuation of investigations on echinoderms.
Dr. W. A. Setchell. Report on general relations of flora of Tahiti.
Dr. T. Wayland Vaughan. Reports on corals collected in the Samoan Islands and on fossil mollusks of the Bowden marl of Jamaica. (J. Edward Hoffmeister and W. P. Woodring.)

Mr. Mills rendered assistance in the collection of *Valonia* from the sea-water in the vicinity of Miami for use in investigations undertaken at the Miami Aquarium by Mrs. M. M. Brooks, of the U. S. Public Health Service; he also collected plankton for a period of three months for the use of Dr. Fox, of Gonville and Caius College, Cambridge, England.

REPORTS OF INVESTIGATORS.

Breeding Experiments with Cerions, by Paul Bartsch.

In order to add two new elements to the cerion breeding experiments conducted on the Florida Keys, it became necessary to make a trip to Porto Rico, where a new color-banded form was discovered some time ago by an expedition of the New York Academy of Sciences. Dr. Bartsch secured passage on the Navy transport *Henderson* on May 2 for San Juan, Porto Rico. From there he went to Guanica Bay, where a week was spent in intensive collecting about the entrance to Guanica Harbor. Here a large amount of cerion material was secured. The return trip from Porto Rico was made on the U. S. Navy transport *Kittery*.

A second expedition in search of a spirally striated cerion, reported from the southeastern Bahama Islands, was undertaken on August 9, when Dr. Bartsch left on the Army transport *St. Mihiel*, from the Brooklyn army base, for San Salvador, Bahamas. Through the kindness of the Army and Navy, a landing was made at Cockburn Town, and two weeks were spent in intensive collecting on this island. Unfortunately, Dr. Bartsch's efforts determined the fact that the spirally striated cerion does not occur on San

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[1] Situated at Tortugas, Florida.

Salvador. While a very large series and a good many new species of cerion were discovered, the element in question was actually not obtained. At the time of the present writing, Dr. Carlos de la Torre, President of the University of Havana, who has brought his cerion collection to the U. S. National Museum for comparison and study, has among them a strongly spirally striated form from Cabanas, which is a little west of Havana. It will be easy, therefore, to secure the desired material at that place.

After two weeks' stay on San Salvador, the transport *Kittery* took Dr. Bartsch from Cockburn Town to Guantanamo, Cuba, whence the journey to Key West was by rail and boat.

At Key West he was joined by Mr. Mills, the chief engineer of the Marine Biological Laboratory. They proceeded to the Tortugas with the *Velella*, stopping at the intermediate keys to examine the cerion plantations.

At the Tortugas careful notes were taken on the various colonies, and two new colonies were established: one of Porto Rican cerions in the southern part of the island; one of the San Salvador cerions near the laboratory. On the return trip the keys between Key West and Miami containing colonies were examined and 150 living specimens from the hybrid colony on Newfound Harbor Key were brought to Washington, where they have been carefully treated for anatomic study, and it is intended to have 100 specimens of these dissected in order to determine to what extent the internal anatomy is changed through hybridization. So far as known, no reliable data are available on this topic.

As usual, Dr. Bartsch kept careful notes on all birds observed on the keys, and he also took a series of under-water moving pictures among the coral reefs of the Tortugas.

Studies on Permeability with reference to Acids, Alkalies, Bicarbonates, and Arsenic, by Matilda M. Brooks.

Mrs. M. M. Brooks carried out studies on permeability with reference to acids, alkalies, bicarbonates, and arsenic. The marine alga *Valonia*, which grows only in tropical waters, is specially adapted to such studies. It consists of a single large cell with a central vacuole filled with sap. This sap can be expressed and analyzed by direct chemical methods, thereby affording an opportunity for direct observation of the permeability of the plant to substances of various kinds. In this way, many theories which have been advanced in this respect can be definitely demonstrated to be either wrong or correct.

Field Investigations on the Variation, Distribution, and Evolution of Species of the Genus Partula, by Henry E. Crampton.

The months from May to September of 1923 were devoted to field-work in Moorea, the island adjacent to Tahiti in the Society Group, and the area on which the present researches are now focused. The previous surveys of Moorea, made in 1907, 1909, and 1919, resulted in the discovery of notable changes in the endemic species of the island since the time of Garrett's pioneer studies; such changes were manifested not only in the enlargement of their realms of occupation, but much more significantly in the individual and colonial biological characters of the land-snails in question.

The work of 1923 was in effect a re-survey of the entire island, and by virtue of its more intensive nature it was successful beyond anticipation;

more than 30,000 specimens were secured from over 50 localities. On the basis of personal collections and observations, proof has been obtained that collective and individual evolutionary changes have taken place in the Moorean species of *Partula* even in the brief interval from 1907 to the present time. A number of new mutations has been added to the list of those found earlier. Finally, in a remote area of interior forest, a new species was found which is closely similar to certain forms of the island of Raiatea, more than 100 miles distant; this discovery strongly supports the contention that a large land-mass formerly existed in southern Polynesia. The abundant material is now in process of qualitative and quantitative analysis.

Studies on the Composition of Sea-Water, by Charles B. Lipman.

The investigations of the past year on the composition of sea-water have been continued, although progress has been slow. The difficulty of obtaining expert analytical assistance in this study prevents the possibility of turning out a great amount of work, but the analytical work is going forward and during the past year samples of sea-water from certain parts of the Oregon and California coast have been analyzed. The gradually accumulating evidence is substantiating the conclusion reached on the basis of earlier analyses to the effect that sea-water is a much more variable substance in its chemical composition than has hitherto been appreciated. Moreover, it is becoming evident from the analytical results thus far obtained that some of the important constituents of sea-water which have never been determined (or if determined, never reported) may prove to be of very great significance in our physiological studies, both as regards marine plants and marine animals.

A detailed statement with regard to these studies on the composition of sea-water may be possible within a year or more.

Observations upon Submarine Color Photography, the Food and Rate of Digestion of Fishes, and the Power of Discrimination and Association in the Gray Snapper, by W. H. Longley.

My stay at Tortugas from June 6 to August 25 and the excellence of the arrangements in the interest of my research make it possible to report progress in several lines of inquiry.

First, it appears that within certain limits submarine color photography may be undertaken successfully. This has been demonstrated by securing autochromes of corals, sea-anemones, sedentary worms, etc. The sole restriction in the application of the process to work in shallow water of clear tropical seas lies in the fact that an exposure of 10 to 12 seconds is necessary, a period during which few animals that are not both sedentary and rather rigid remain unmoved by wave or tide and undisturbed by the photographer's preparations. But even with this limitation, use of color photography in reef studies will doubtless permit more apt representation of the general appearance of submerged portions of the reef than will any method hitherto applied.

Besides color photographs, which will serve to define some of the more striking color notes in the environment of Tortugas fishes, others were secured portraying species, or facts in behavior of species, of which no record had been obtained earlier. That part of the work which deals with the coloration and habits of Tortugas fishes may now, therefore, be prepared for publication.

In addition to making miscellaneous observations upon the habits of fishes, special note was taken of the reaction of a number of species to the palolo worms available to them in myriads for a few hours on July 7 in their annual swarm, which as usual fell within 4 days of the last quarter of the July moon. As is well known, the posterior sexual segments of the mature worms are cut off from the anterior vegetative portion, rise to the surface in one piece in the early dawn, and after a short time burst, freeing the eggs and sperm-cells. But before the discharge of the sex-cells takes place, the worms occur at Tortugas with an average frequency of perhaps two or three to the square foot of surface over an area of many square miles.

Only less impressive than their teeming multitudes is the tax levied upon them by the predaceous fishes of the region. Foremost among these is the gray snapper (*Neomœnis griseus*). The snappers are for the most part nocturnal bottom feeders; they cease searching for prey and return to their schooling places shortly after daylight. But on the morning of the palolo swarm they remain longer afield and may sometimes be seen feeding upon the worms at the very surface of the water. 14 snappers, 10 to 11 inches long and taken with dynamite about sunrise on "palolo day," contained from 8 to 28 c.c. of worms each. One 12 inches long contained 55 c.c. and two 14-inch fishes contained 45 c.c. each. These 17 fish therefore contained 364 c.c. of the worms, which is equivalent to saying that they had eaten about that number, or roughly 20 each. How many more, if any, they might have eaten, if left to themselves, it is impossible to say. Food of other kind than the worms appeared in their stomachs in less abundance than on other days. But the total quantity of food present far surpassed that to be found on ordinary occasions.

Snappers plainly secure much less food upon the average than they are able to eat. It is also clear that their diet depends more largely upon the availability than on the abundance of the organisms fed upon, for these exceedingly common and acceptable annelids are rarely found in their stomachs ordinarily. Their reaction on this occasion demonstrates again, as Howard has demonstrated in the case of secondary and tertiary insect parasites, and as Forbes has demonstrated in the case of certain orchard pests, that natural agencies operate at once to reduce the numbers of any species which undergoes sudden increase.

Fish such as the yellow goat-fish (*Upeneus maculatus*) and the various species of grunts, in the dietary of which annelids constitute a constant element, are gorged with them on the day of the great swarm, not mingled with sand, as is usually the case when they are taken from the bottom, but wholly unmixed with foreign materials. Some species, such as the black angel-fish (*Pomacanthus arcuatus*), which feeds commonly upon blue-green, green, and brown algæ, as well as upon sponges, bryozoa, etc., join in the attack upon the worms. But specimens of *Lactophrys triqueter*, *Sparisoma viride*, and *Microspathodon chrysurus* had eaten none. Neither had a large Spanish angel-fish (*Angelicthys isabelita*) done so, although Linton has reported annelids in its stomach contents at Bermuda.

Very striking is the contrast between the results in the case of the gray snapper and the related species, the schoolmaster (*Neomœnis apodus*). Of this species, 16 specimens, ranging from 9.5 to 11.5 inches in length, and feeding commonly upon the same general sort of food that the gray snappers do, contained only from 1 to 15 c.c. of the palolo worms, 92 c.c. in all, or less than 6 c.c. upon the average. Observations of this sort, when repeated, completely disprove the idea that even closely related species, apparently living much the same lives, have the same habits.

In studying the stomach contents of snappers I have been struck by the comparative rarity of specimens of the food-fishes not well advanced in the process of digestion. My attention being thus called to the rate of digestion in these fishes, a few experiments were made bearing upon the point. Fishes of various genera, *Iridio, Scarus, Hœmulon, Eupomacentrus, Siphostoma, Monacanthus,* etc., as well as crabs and shrimps, were marked with thread, fed to the snappers, and in two instances recovered from their stomachs after having been subjected to the process of digestion for 2¼ and 3½ hours, respectively. At the end of the shorter period most of the fishes were readily recognizable by one who knows the fishes of the region. Skin and pattern were usually intact upon any face not directly in contact with the lining of the stomach. Crabs such as *Mithrax hispidus* and various small Portunidæ were practically unchanged in color or texture. After 3½ hours specimens of *M. hispidus* were still green, firm, and intact, though a shrimp of larger size, perhaps bitten in two before being swallowed, was far advanced in digestion. Many of the fishes still showed bits of their original color pattern. Most of them were identifiable by jaws, pharyngeal teeth, or other peculiarities. Some, however, had passed the point where their species could have been more than guessed at, if they had not borne my marks of identification. From comparison of marked fishes and crustacea recovered, with other specimens eaten under natural conditions, enough was learned to prove that snappers in general feed more or less continuously through the night.

In reports of earlier years much has been written regarding the obliterative coloration of tropical reef fishes. To pass from a study of such color to a consideration of the agencies that have possibly called it into being is no long step. Among these agencies must be included natural selection through attacks of predaceous fishes. But if these have worked in any large way in directing racial development of color and pattern toward obliterative effects, it may well be anticipated that they have decided powers of discrimination in respect to colors and patterns.

Since Professor Reighard[1] has already investigated the ability of the gray snapper to discriminate colors, I undertook only a study of their power to distinguish two simple patterns and to form associations between such patterns and the quality of distastefulness. Minnows of the species *Atherina laticeps* provided the test material. These fishes are so lightly pigmented as to be almost uniformly pale in coloration. They were given either a longitudinal dark stripe through the eye to the base of the tail, or two transverse dark bands upon the body, somewhat narrower than the interspaces, by painting them with silver nitrate.

In the first test, which was several times repeated on different groups of snappers, 25 unmarked atherinas were first fed, after which 25 striped and 25 banded fish came in alternation with one another, to be followed themselves at last by 25 plain fish like those first offered. The results of these tests were uniform. The unmarked fishes were accepted with least hesitation, and the striped more readily than the cross-banded.

In order to determine whether the banded fishes were taken least readily merely because they were darkest, or for another reason, a second series of tests was made, in which the striped fish were as before, while the banded ones were of two kinds. The first of these had dark bands that were broader than those on the fishes in the preceding experiments, while those of the second had them so much narrower that they were not as much darkened by them as the striped fish were by their markings. In tests with colonies which had had no previous experience in the matter, when the snappers were fed first a stripe, then a narrow band, a stripe, a broad band, and so on indefinitely, it appeared that stripes were still accepted more readily than bands, suggesting that there is something about the banded pattern itself, as opposed to the stripe, that causes the snapper to hesitate longer before accepting it. But the experiment should be repeated.

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[1] Papers frem Department of Marine Biology, Carnegie Inst. Wash. Pub. No. 103. 1908

Plain, banded, and striped fishes are taken at first at different rates, but, as the feedings are repeated from day to day, the differences in rate disappear. When, then, in two colonies, one at the laboratory dock and the other under one of the docks at Fort Jefferson, the point had been reached where plain, striped, and banded fishes were being taken at the same rates, the established procedure was changed.

At the laboratory dock the striped fishes were made distasteful by sewing into their mouths bits of the tentacles of the medusa *Cassiopea*, while at the fort it was the banded that were so treated. Without attempting to enter into details, it may be stated that after a time the snappers at the laboratory dock showed a marked preference for the banded fish, and those at the fort for the striped, even when neither of the two sorts offered to a single colony had been made distasteful through use of the medusa tentacles. It may therefore be accepted tentatively that the snappers are able to discriminate between the banded and striped food-fishes offered them and to associate the distastefulness mentioned with either of the patterns. Since the reaction once established remained unchanged in both cases at a later time of testing, it may be added that the snappers not only discriminate between the two patterns, and form associations between either of them and qualities of the fishes displaying them, but the association persists for a longer or shorter time.

It is not possible at this time to say how often a colony of 50 or 100 snappers must suffer from the *Cassiopea* sting before it avoids the fishes which carry it, for it is highly probable that in my early experiments the stings were not active in all the atherinas. A strong suspicion that such was the case led to an investigation of the viability of *Cassiopea* fragments under the experimental conditions. As one result of this investigation it appeared that when 125 atherinas of medium size have been preserved in 1 per cent formalin for some time it is not sufficient to rinse and soak them in a large quantity of sea-water, even for 2½ hours, before proceeding to use them. For when such fishes, at the end of 2½ hours, are again rinsed, soaked, and put in sufficient fresh sea-water to cover them, and this smaller amount is twice or thrice changed at intervals of half an hour, the extract continues to give positive results when tested for formalin and kills jellyfish in a short time.

Therefore I feel justified in expressing my conviction that Professor Reighard's experiments are not conclusive. It is highly probable that the *Cassiopea* fragments which he believed were still alive, but did not test to determine whether such was the case, had had their effectiveness greatly reduced or destroyed by formalin extracted from the fishes in which they were sewed. This conviction is supported further by the fact that his conclusions are explainable (in part at least) upon other grounds than he assumes, and because results of the type he secured are obtainable when fishes are stained and fed as he fed them, but without *Cassiopea* stings at any stage in the experiment.

It is clear, therefore, that although a promising beginning has been made, much that is interesting remains to be discovered regarding the powers of discrimination and association in the gray snapper.

Investigations at Tortugas, by Asa A. Schaeffer.

Distribution of Marine Amebas in Surface Water, Beach Sand, etc.

The method of determining the distribution of bacteria-feeding amebas belonging to the genus *Flabellula,* which was devised and tested in a preliminary way in 1922, was given a more thorough test this season. Thanks to the unusually ample and efficient aid by the members of the crew, a much larger number of tests were made than would otherwise have been possible. In all, 1,016 cultures were set up and examined, including in this number 12 controls. Following is a synopsis of the experiments:

Experiment 1, June 8.—Wet beach sand, over a circular area of 594 sq. cm. and to a depth of 7 cm., was collected a meter below high-tide line and close to the water's edge during a falling tide on the northeast end of Loggerhead Key. The sand was gently washed with 10 liters of clear sea-water dipped up in sterilized vessels a short distance from the dock. The water was then drained off and placed in 101 sterilized 100 c.c. bottles, a small piece of autoclaved *Sargassum* was placed in each bottle, and the bottles were closed with the sterilized cotton plug. The bottles were then set aside for 9 to 11 days and examined for amebas. From 3 to 15 minutes were spent on each bottle, usually the shorter period, to note the presence of *Flabellula mira* and *F. citata* particularly, but the presence of other species of amebas was also noted, as well as the presence of ciliates of whatever species and of large flagellates. (As the purpose of these experiments was to test the presence of the most widely distributed marine amebas, *Flabellula mira* and *F. citata,* no time was taken to positively identify other species of protozoa.) Of the 101 bottles in this experiment, 47 contained amebas, 61 contained ciliates, 7 flagellates, while 36 bottles contained *Flabellula mira,* and 6 *F. citata.*

Experiment 2, June 12.—An hour after low tide, 101 bottles were filled with water from the moat at the fort, as far as possible from the moat opening. The bottles were supplied with *Sargassum,* as in the previous experiment, and then set aside for 10 days. Results of the examination are tabulated below.

Experiment 3, June 12.—At a point in the lagoon a few hundred meters west of the moat-opening of the fort, 104 bottles were filled with surface water and supplied with *Sargassum* and set aside for 11 days. The results of the examination are tabulated below.

Experiment 4, June 22.—A pit was dug in the sand in the northeast end of Loggerhead Key, among bushes of Bay Cedar and *Tournefortia,* a few centimeters below the water-level at low tide. Care was taken not to let any of the vegetable mold, débris, and sand of the surface fall into the pit. The sand had apparently been undisturbed for a number of years. Of the water which collected in the pit, 104 bottles were filled and treated as in the other experiments. The examination at the end of 10 days' incubation gave the results shown below in the table.

Experiment 5, June 26.—101 bottles were filled with water from the Gulf Stream, 10 miles west of Loggerhead Key—that is, water which probably had not touched a shore while flowing 1,000 miles or more, remaining during this time under practically uniform conditions. *Sargassum* was added and the bottles set aside for 10 days. The results of the examination are shown below.

Experiment 6, June 26.—104 bottles were filled with water as in experiment 5. To each bottle was added a leaf of *Sargassum* having a surface of about 2 sq. cm. The *Sargassum* leaves were all taken from a single, rapidly growing piece floating by itself, which was gently lifted out of the water 10 miles west of Loggerhead and handled with sterilized instruments. A piece of autoclaved *Sargassum* was added as usual. 13, 14, and 15 days later the bottles were examined with the results shown below.

Experiment 7, June 29.—A pit about 1 meter deep was dug in Sand Key (Tortugas), which has no vegetation, a few centimeters below the low-tide line and 100 bottles were filled with the water which seeped in. *Sargassum* was added as in the preceding experiments. The results of the examination 12 days later are tabulated below.

Experiment 8, June 29.—About 3 c.c. of undisturbed leaf mold from under bay-cedar bushes was placed in each of 20 sterilized bottles filled with sea-water. 13 days later they were examined with the results shown in the table. 5 bottles similarly set up were autoclaved 30 minutes at 12 pounds pressure as a control.

Experiment 9, June 29.—20 bottles were prepared as in the preceding experiment except that about 20 dead *Tournefortia* leaves, still hanging on the plant, were placed in the bottles instead of leaf mold of the bay cedar. The results of the examination 14 days later are shown in the table.

Experiment 10, June 29.—In each of 20 bottles prepared as in the two preceding experiments, 1 c.c. of coral sand from the surface (not deeper than 1 cm.) of the beach, 10 meters above the high-water line and 4 meters from any vegetation. The results of the examination 14 days later are shown in the table.

Experiment 11, June 29.—In each of 20 bottles prepared as in experiments 8, 9, and 10 was placed dried eel-grass (*Thalassia*) from thin, loosely packed rows about 3 meters above the high-tide line, which had been lying undisturbed for several months at least. In each bottle the fragments of eel-grass amounted to about 250 cm. long by 1 cm. in width. An examination 14 days later gave the results shown in the table.

Experiment 12, July 13.—102 bottles were filled with surface sea-water, taken about 200 meters northwest from the laboratory dock on Loggerhead Key, where the water averaged about a fathom in depth. The wind had been from the west and the northwest for about a week previously, and considerable amounts of algæ had been torn loose and swept up on the beach. This stirring up of the water did not increase the number of amebas in the surface layer, as the results of the examination 9 days later showed. See table below.

Experiment 13, July 13.—Control. 101 bottles filled with sea-water and plugged with cotton were autoclaved at zero pressure for 10 minutes. After the bottles had cooled a small piece of autoclaved *Sargassum* (zero pressure, 10 minutes) was added to each bottle and the plug replaced. No amebas, flagellates, or ciliates were present in any of the bottles, showing that the method of sterilization employed in these experiments is reliable.

Table showing distribution of amebas at Tortugas.

Experiment No.	Distribution.	No. of cultures.	No. of bottles containing				
			F. mira.	*F. citata.*	Total amebas.	Ciliates.	Flagellates.
1	Amebas in beach sand	101	36	6	47	61	7
2	Amebas in moat water	101	19	1	20	17	7
3	Amebas in shallow water	104	4	0	5	6	0
4	Amebas in sand under vegetation	102	53	1	54	53	91
5	Amebas in Gulf Stream	101	4	2	6	0	0
6	Amebas on floating Sargassum	104	50	0	63	5	0
7	Amebas in sand (Sand Key)	100	6	0	7	0	0
8	Amebas in leaf mold of bay cedar	20	11	0	15	2	0
	Controls	5	0	0	0	0	0
9	Amebas on Tournefortia leaves	20	2	0	2	2	0
	Controls	5	0	0	0	0	0
10	Amebas on dry beach sand	20	2	0	8 (?)	4	0
	Controls	5	0	0	0	0	0
11	Amebas on dry eel-grass	20	18	0	19	0	0
	Controls	5	0	0	0	0	0
12	Amebas in stirred-up sea-water	102	3	0	3	2	2
13	Control	101	0	0	0	0	0

These experiments were designed to test the abundance of amebas (or cysts) in all the general regions of the Tortugas Keys, in the surface water of the Gulf Stream near the shore and far out, and on floating *Sargassum*. The results as a whole show that the method adopted is generally satisfactory for determining the distribution of amebas.

The results of experiments 3, 4, and 11, comprising 307 cultures, of which 14 bottles contained amebas, show that the surface water of the Gulf Stream in the Tortugas region contains about 4.56 amebas per 10,000 c.c. of water. Experiments 1, 4, and 6 show that amebas are much more abundant on a solid support. Experiments 8, 9, 10, and 11 show that amebas may exist for considerable periods in the encysted stage exposed to tropical sunlight. *Flabellula mira* forms cysts, but *F. citata* apparently does not. The distribution of ciliates corresponds roughly to the distribution of amebas in the cultures. Since the amebas in question and the ciliates feed on bacteria, it is probable that this correspondence is further proof that the distribution of amebas as well as of ciliates is conditioned by the presence of comparatively rich bacteria cultures.

F. mira has come up much more frequently than *F. citata*, and yet in previous years both at Tortugas and at Cold Spring Harbor, New York, *F. citata* nearly always came up in enormous numbers, in large mass cultures of various kinds of algæ selected at random. No explanation for these apparently conflicting observations can yet be given.

It is the intention to follow up this study of the quantitative distribution of amebas, if possible, with another study of the distribution of amebas on the sea-floor down to several hundred fathoms, in the same general region. The ultimate object is to secure as adequate an idea as possible of the quantitative distribution of amebas in the Gulf Stream. It is believed that such data would be of interest not only to students of amebas, but to biologists generally, for we have no such data now regarding any of the lower animals.

Observations on New and Imperfectly Known Species of Amebas.

Two new species of amebas were found. One of them belongs to the genus *Pontifex* and was found in considerable numbers in cultures made up from floating algæ, in the concrete tanks (see below), and in the tidal pool on Sand Key (Tortugas). This species is large and conspicuous and it is safe to say that it was not present in the waters of Tortugas in the seasons of 1919, 1921, and 1922, for daily observation of numerous cultures during these seasons revealed none of them. The species is very interesting from several points of view but a full description of it must be deferred until later.

The other new species is very small but of very distinctive shape and behavior. It came up in considerable numbers in the concrete tanks and in several of the cultures made up from floating algæ. A full description will be published later.

A large number of *Gibbodiscus gemma*, which was described from a few individuals in 1921 at Tortugas, came up in the tidal pool in Sand Key (see below). They conformed to type, but there was considerable variation in the presence and size of cubical crystals, and the shape during locomotion is more often roughly circular or oval with the broad side advancing, rather than oval with the narrow side advancing as previously described. A revised description will be published later.

In addition to the two new species mentioned above, representatives of the following 14 previously described species were seen in the course of examination of the various mass cultures set up during the season: *Mayorella conipes, M. crystallus, Flabellula mira, F. citata, Thecamœba rugosa, T. orbis, T. hilla, Trichamœba sphœrarum, Vexillifera aurea, Hyalodiscus fulvus, Dactylosphœrium acuum, Pontifex maximus, P. minimus, Gibbodiscus gemma,* and *Rugipes vivax.* The present season was, therefore, more favorable to growth of amebas than last season, when only 8 species not previously described were seen. Altogether 29 new species have now been described from Tortugas.

A tidal pool was discovered in the middle of Sand Key (Tortugas) with considerable quantities of green and brown algæ in it. The bottom was in fact entirely covered with algæ. At low tide there was about 20 cm. of water in the pool at the deepest part, and the pool was about 4 meters in diameter. At high water the pool was about 8 by 10 meters in extent. The following 7 species of amebas were found in it: *Thecamœba rugosa, T. orbis, Mayorella conipes* in large numbers, *Vexillifera aurea, Gibbodiscus gemma* in large numbers, *Pontifex horridus* (new species) in large numbers, and *Trichamœba sphœrarum.* Sand Key had not been visited for several years and it is therefore impossible to say how long the tidal pool has existed there. Its value as an aid in studying distribution is at once recognized. A somewhat similar but smaller pool was blasted into East Key in the hope that a natural culture for amebas will form there.

Observations on the Effect of Nitrate on the Growth of Plankton.

The concrete tank described in my last year's report was set up in the same way as last year and the same quantity of nitrate added. Another tank of the same size was constructed and set up, with the same amount of running water, but without nitrate. Two thicknesses of cheese cloth were stretched over the tanks at a height of about 0.5 meter to shield them from too much direct sunlight. (It was thought last year that the high temperature which developed in the tank during midday was inimical to the amebas.)

On June 30 an examination of the tanks was made. The tank with the nitrated water contained large numbers of brownish flagellates, mostly of the genus *Amphidinium.* When some of the water was placed in a petri dish it looked slightly brownish. A relatively small number of diatoms were found, only slightly more than in the other tank. About equal numbers of *Mayorella conipes* were found in the two tanks. These fed mostly on diatoms. Very few flagellates were found in the other tank.

After examination the nitrate was omitted from the first tank and from now on (June 30) nitrate was added to the second tank. On July 17 another examination was made with the following results:

In tank No. 1, now without the nitrate: (1) the flagellates had gone down to perhaps one-fourth the number present on June 30; (2) considerable numbers of very small diatoms had come up; (3) appreciable numbers of *Pontifex horridus, Mayorella conipes,* and *Trichamœba sphærarum* had appeared. In tank No. 2, now with nitrate in the water: (1) about three-fourths as many flagellates were found in this tank as in No. 1; (2) very few diatoms were present; (3) large numbers of *Mayorella conipes* were present but no other amebas. These amebas fed on the flagellates.

The addition of nitrate to the water evidently caused an appreciable increase in the number of flagellates, but the effect was not so striking as in the experiments last season upon the diatoms. That the diatoms did not come up this season and the flagellates not last season may have been due to their rarity or absence from the Tortugas waters in the respective seasons. No special search was made for the flagellates in other seasons, but they were certainly not as plentiful during the past three seasons as they were this season; and this season the large diatoms which were so plentiful in the tank in 1922 were almost if not entirely absent from my cultures. (The necessity for a careful search was not appreciated until a few days before I left Tortugas.) Further experiments will show by comparison with those already performed what the effect of an excess of nitrate is on flagellates and diatoms and indirectly on the larger amebas.

Observations on Spiral Movements of the "Atlantic Palolo" and on Salpa.

The study of spiral movement in organisms generally is an outgrowth of my observation in 1917 that amebas move in sinusoidal paths when free to do so. Observations have been collected on many animals and motile plants since that time, and it appears now that the tendency to spiral movement is universal among organisms and that the explanation of this tendency can best be obtained by continued observation on as many different small groups of organisms as possible.

The "Atlantic Palolo" (*Laodice fucata*) swarmed on July 7 this year. The general observations of Mayor published in 1908 are confirmed here. The detached posterior (sexual) end of the worm swims about, rotating to the right (like a right-handed screw). The worms can not be induced to swim with the anterior end ahead, not even small immature worms. Neither could the anterior ends of worms, which had set free the posterior sexual ends, be stimulated to swim with the anterior end ahead. The sperm cells swim in spiral paths, rotating to the left. The sperm cells are large and swim relatively slowly so that their movements may be readily made out. They also have the habit of frequently attaching themselves by the end of the flagellum, whereupon they swing in large circles to the left, the head of the sperm describing the circle while the end of the tail is in the center of the circle. They turn to the left, that is, when fastened to the surface of the slide; when fastened to the under surface of the cover-glass they travel to the right as one looks at them through the microscope. The reason for this is obvious when one remembers that the sperm head revolves on its long axis to the left when swimming freely. This observation is of great value in this connection for it serves as a key to interpret the movements of many kinds of sperms that swim too rapidly to enable one to see directly the direction of rotation; all that is necessary now is to observe those sperm cells that are anchored and determine in what direction they swing, and whether they are attached to the surface of the slide or of the cover-glass. The behavior when swimming freely may then be inferred.

The fertilized eggs become ciliated 10 hours after fertilization and swim at first in an uncoordinated manner. Later they swim in a well-coordinated manner, rotating to the left on their long axis. At first the path is a straight line, but a spiral path soon develops and after 6 days the spiral becomes very marked, the spiral turns having a diameter from one to three times the diameter of the larva. Along with a constant increase in the width of the spiral as the larva develops there is a constant decrease in the length of the spiral until the latter becomes practically zero and forward progression stops. The larva then swims around in small circles in the same spot; it soon sinks to the bottom and adopts crawling as a method of locomotion.

Organisms like the Atlantic Palolo are particularly valuable in studying spiral movement because three different stages of its existence move in spirals. An important question is: Do the different stages in such animals turn in the same direction; and if not, as in the Atlantic Palolo, where the mature worm turns to the right and the sperm and larva to the left, what relation is there between swimming with the *posterior* end ahead and *reversing* the direction in which the worm as a larva turned?

The movements of *Salpa democratica* and *S. fusiformis* were also studied, for the method of locomotion in these animals differs altogether from that of any other organism which is known to swim in spiral paths. The chain form of *Salpa democratica* rotates on its long axis to the right in swimming ahead in a close spiral path. Young detached individuals (5 mm. to 8 mm.) swim in very open spirals soon after detaching themselves from the chain, making very little forward progress. Older individuals and young individuals detached for a time swim in closer spirals and make more progress forward. The nucleus is on the inner side of the spiral. The solitary form was not studied carefully enough to make definite statements about their movements.

Salpa fusiformis, solitary form, rotates to the right whether swimming forwards or backwards. They swim in large, open circles, making little forward progress. They rotate with the nucleus on the outer side of the spiral. Further details will be given in a paper on spiral movements.

Observations on the Formation of Beach Rock (?) in the Laboratory.

In the interest of geologists and biologists I am adding a brief note to my report, about the formation of thin sheets of rock-like material in some of my protozoan cultures which were set up with material from Tortugas, Key West, and Miami, Florida. The cultures were set up in quart jars with a considerable quantity of coral sand, algæ, and sea-water. After remaining practically undisturbed for about 18 months there was found on the surface of the sand a layer of rock-like material which consisted of coral-sand particles cemented together, apparently with fine calcareous material. Under the microscope the material resembled beach rock very closely. It occurred to me that essentially similar processes might account for the formation of the rock in the jars and of natural beach rock, and I therefore turned over the cultures with data to Professor Richard Field, of the Department of Geology, Princeton University, who kindly agreed to examine the material.

A Botanical Reconnaissance of Tahiti in the Summer of 1922, by W. A. Setchell.

Progress has been made in working over the collections and towards drawing up reports. Various of the Spermatophytes have been submitted to E. D. Merrill (Manila), I. Burkill (Singapore), A. S. Hitchcock (Washington), R. Schlechter (Berlin-Dahlem), and Paul Standley (Washington), who have furnished identifications, notes, etc. A list, with notes, is in process. The Pteridophytes have all been submitted to W. R. Maxon (Washington), who has his report practically completed. The mosses are in the hands of V. K. Brotherus (Helsingfors), who will report soon. W. R. Pearson (Manchester), to whom the Hepaticæ were sent, died before he had proceeded very far and this collection is at present among his effects. The Fungi are ready but have not been sent to any specialist. E. A. Vainio (Helsingfors) has submitted his report on the Lichens and it will go to press very soon. Reports on the soils (C. B. Lipman, Berkeley), the rock samples (G. D. Louderback, Berkeley), and the corals (T. Wayland Vaughan and J. Edward Hofmeister) are under way or have been made in preliminary fashion. The preparation of the report on the general aspects of the vegetation and on the algæ, particularly of the reefs, is now in advanced condition.

Investigations on the Hybridization of Echinoids conducted at the Misaki Marine Biological Station of Tokyo Imperial University, from April 24 to August 16, 1923, by D. H. Tennent.

During these investigations, material for the study of the morphology of the chromosomal groups of 9 echinoids was obtained. This includes series of eggs from 7 straight fertilizations and from 11 cross-activations. Of the latter, 8 are from 4 reciprocal crosses and 3 are from cross-activations made in one direction only. Methods were devised which enabled me to obtain above 95 per cent activation in every cross made.

The success of the investigations lies in the application of observations on the processes of straight fertilization in the species whose spermatozoa were used as foreign spermatozoa. The investigations have established clearly the fact that the processes of fertilization differ in different species of echinoids. In some, e. g., *Temnopleurus toreumaticus*, the cortical reaction is striking and a widely separated fertilization membrane is formed. On the other hand, the egg of *Heliocidaris tuberculata* never forms a widely separated fertilization membrane, the thick membrane which is formed after activation appearing slowly and investing the egg rather closely.

Further, the internal changes occurring between the initial cortical reaction and the first division of the egg are not the same in all eggs.

The species of echinoids which have been used in the investigations are: *Strongylocentrotus pulcherrimus, Heliocidaris tuberculata, Clypeaster japonicus, Echinarachnius mirabilis, Temnopleurus toreumaticus, Mespilia globus, Astriclypeus manni, Peronella lesueuri, Toxopneustes pileolus.* The reciprocal crosses were between *Heliocidaris* and *Clypeaster, Temnopleurus, Mespilia,* and *Astriclypeus.*

Hitherto, the methods commonly used in obtaining cross-activation, when activation was not obtainable in normal sea-water, have been that of allowing the eggs to stand in sea-water for 1 to 4 hours before insemination, or that of increasing the alkalinity of the sea-water by the addition of NaOH. No satisfactory explanation for the success of these methods has been given.

If it is true that NaOH and such monovalent salts as NaCl increase the permeability of the egg membrane, while such bivalent salts as $CaCl_2$ and $SrCl_2$ decrease the permeability of the membrane, we have a logical explanation of the reason for the success of the methods that I have devised, as well as the explanation of the success of the empirical methods which have been found of use in other cases.

In some of the cross-activations which I have made, it has been necessary to remove internal block to the union of the egg and sperm nuclei after the cortical block has been overcome. This may be done readily by the use of hypertonic sea-water.

The following methods proved successful and gave better than 95 per cent activation and cleavage.

1. *Heliocidaris* eggs×*Clypeaster* sperms. Inseminated in normal sea-water with exceedingly good *Clypeaster* sperm.
   Clypeaster eggs ×*Heliocidaris* sperms. Inseminated in 100 c.c. sea-water+2 c.c. 2.5 M NaCl+1.2 c.c. N/10 NaOH.
2. *Heliocidaris* eggs×*Temnopleurus* sperms.
   - *a.* Eggs in 100 c.c. sea-water+2 c.c. 2.5 M NaCl.+1.2 c.c. N/10 NaOH for 6 minutes, then inseminated.
   - *b.* After 10 minutes tranferred from *a* to 100 c.c. sea-water+6 c.c. 2.5 M NaCl.
   - *c.* After 20 minutes transferred from *b* to 82 c.c. sea-water+18 c.c. 2.5 M NaCl.
   - *d.* After 15 minutes transferred from *c* to sea-water.

   Temnopleurus eggs ×*Heliocidaris* sperms. Inseminated in 100 c.c. sea-water+1.2 c.c. N/10 NaOH.
3. *Heliocidaris eggs*×*Mespilia* sperm.
   - *a.* Eggs placed in 100 c.c. sea-water+2 c.c. 2.5 M NaCl for 5 minutes then transferred to
   - *b.* 100 c.c. sea-water+1.2 c.c. N/10 NaOH. and inseminated. After 3 minutes eggs transferred to
   - *c.* 100 c.c. sea-water+3 c.c. 2.5 M NaCl. After 40 minutes transferred to
   - *d.* Sea-water

   Mespilia eggs×*Heliocidaris* sperm. Inseminated in 100 c.c. sea-water+1.2 c.c. N/10 NaOH. After 15 minutes transferred to 86 c.c. sea-water+14 cc. 2.5 M NaCl for 20 minutes, then to normal sea-water.
4. *Heliocidaris* eggs×*Astriclypeus* sperms. Eggs placed in
   - *a.* 0.625 M $CaCl_2$ for 3 minutes.
   - *b.* Then 800 c.c. sea-water+5 c.c. N/10 NaOH+sperms. After 10 minutes to
   - *c.* Sea-water.

   Astriclypeus eggs×*Heliocidaris* sperms. Eggs placed in 100 c.c. sea-water+2 c. c. 2.5 M NaCl. and inseminated. After 10 minutes transferred to sea-water.
5. *Heliocidaris* eggs×*Peronella* sperms.
   - *a.* Eggs placed in 0.625 M $CaCl_2$ for 3 minutes,
   - *b.* Inseminated in 800 c.c. sea-water+5 c.c. N/10 NaOH.
6. *Heliocidaris* eggs×*Toxopneustes* sperms. Eggs inseminated in 100 c.c. sea-water+2 c.c. 2.5 M NaCl.+1.2 c.c. N/10 NaOH.

With the exception of 6, for which material was obtained but once, the methods as given are those reached after careful testing of different concentrations of the salts used, and the methods finally selected have all been tested several times. Details of the comparison of the effects of treatment with $CaCl_2$ and $SrCl_2$ with NaCl are interesting and important, but must await the full presentation of the results of the investigation.

During the past year, working in the zoological laboratory of the University of California, I have completed and prepared for publication the results of my investigations made while a member of the expedition to Torres Strait. These reports deal with the cytology and embryology of *Echinometra mathaei*, *Peronella lesueuri*, and *Salmacis virgulata*, together with a discussion of experiments in hybridization between *Echinometra mathaei* and the crinoid *Comatula pectinata*.

One of my papers, "Studies on the Hybridization of Echinoids (*Cidaris tribuloides*)," has been published during the year as part of Publication No. 312 of the Carnegie Institution of Washington.

Studies of the Molluscan Fauna of the Miocene Bowden Marl of Jamaica; Fossils from Walu Bay, Fiji; and Corals and Bottom Samples from Pago Pago Harbor, by Thomas Wayland Vaughan.

A report was published in the last Year Book of the Institution[1] on the investigations above enumerated, except the one on the Mollusca of the Bowden marl of Jamaica, and what was said there need not be repeated.

Mollusca of the Bowden marl of Jamaica.—Dr. W. P. Woodring, who is making a monographic study of the Mollusca of the Bowden marl reports that about 600 species of mollusks have been described and that the manuscript will be completed early in 1924. During the past year more than 1,000 photographs to illustrate the monograph were made and retouched. The descriptive part of the text is virtually complete, but the discussion of the significance of the fauna is not yet finished.

Fossils from Walu Bay, by W. C. Mansfield, with a brief article by T. W. Vaughan on the Succession and probable Age of the Sedimentary Formations of the Fijis.—Mr. Mansfield's manuscript is complete and the illustrations are now being made. It is intended within a relatively short time to submit this paper with proper illustrations for publication by the Institution.

Corals from Pago Pago Harbor, Samoa.—Mr. J. Edward Hoffmeister has completed the manuscript of his report of the corals collected in Pago Pago Harbor by Dr. Alfred G. Mayor and it will be ready as soon as photographs needed for illustrations have been made and assembled into plates.

Bottom Samples from Pago Pago Harbor, Samoa.—Mr. M. N. Bramlette has completed his descriptions of the bottom samples collected by Dr. Alfred G. Mayor in Pago Pago Harbor and his report will be ready for submission as soon as the results of some of the chemical analyses, made by L. G. Fairchild, of the U. S. Geological Survey, have been incorporated.

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[1] Year Book No. 21 for 1922, pp. 187–189.

DEPARTMENT OF MERIDIAN ASTROMETRY.[1]

BENJAMIN BOSS, DIRECTOR.

During the past year a study of the discordances in meridian observations has thrown considerable light on their nature. The effect of differential refraction upon observations has received special attention. While it is certain that this phenomenon accounts for many of the discordances noted in all meridian observations, which have heretofore been taken out by empirical means if they have been removed at all, the work of the past year has shown that the elimination of these effects by formula would unduly delay the publication of the San Luis and Albany observations, from which the greater part of the discordances have already been taken out empirically. Consequently, it has been decided to publish these observations without employing differential refraction.

REDUCTIONS OF OBSERVATIONS.

The San Luis observations in zenith distance have been completely reduced and the mean declinations for 1910.0 are ready to be put into manuscript. The right ascensions are also reduced to the point where a study of discordant series is being made, preparatory to reducing to the mean position for 1910.0. These should be ready to put into manuscript within a few months. The reductions of the Albany declinations are in an advanced stage, but considerable work remains to be done on the right ascensions.

STELLAR PARALLAX.

An attempt has been made to determine the systematic errors of the Mount Wilson spectroscopic parallaxes, based upon their direct comparison with the trigonometric parallaxes. This method might be presupposed to include a regression factor. Independent evidence is furnished by the data secured from moving clusters of stars, which supports the corrections to the Mount Wilson system derived by the direct-comparison method for the region covering the smaller parallaxes. The agreement is possibly due to the fact that the regression factor has not been taken into account in the formation of the curves on which the Mount Wilson system is based. The corrections derived indicate that for the more distant stars, those whose parallax is less than 0″.02, this system assigns too great a distance, while the nearer stars, parallax 0″.02 to 0″.12, have been placed too near. There are few stars with parallaxes over 0″.12, representing our nearest neighbors in space, but the evidence deduced from the observed material indicates a rather sharp break in the Mount Wilson system at this point. The apparent break may possibly be due to the fortuitous distribution of errors, and to the fact that the correlation curves for faint absolute magnitudes do not follow the form of the curves for the brighter magnitudes. When the material is divided according to type there appear to be systematic differences between the corrections indicated for different types.

The Mount Wilson parallaxes, corrected for systematic error, have been employed in deriving the corrections to other series of parallaxes. These are in essential agreement with the corrections published at Mount Wilson. In a former investigation by this Department, corrections to the trigonometric parallaxes varying with the right ascension were indicated. A rediscussion, including more recent data, yields similar curves for Allegheny, McCormick, and Mount Wilson, but the forms of the curves for Yerkes and Sproul are considerably altered.

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[1] Address: Dudley Observatory, Albany, New York.

PROPER-MOTIONS OF THE CEPHEID VARIABLES.

From correlations of their parallactic and peculiar motions derived from proper-motion and radial-velocity data, supplemented by the discovery that in this class of stars the absolute magnitude is a function of the period, Shapley found in 1918 that the Cepheid variables are exceptionally luminous stars very distant from us, the distances of some of the individual stars being as much as 20,000 light-years. Reasoning upon the assumption that the stars of this class found in the globular clusters are of the same luminosity as those outside of them, he was led to the startling conclusion that the diameter of the stellar system must be about 300,000 light-years, ten times as large as most of the earlier investigators had indicated it to be. One of the most fundamental weaknesses in his deductions seemed to be in determining the mean distance of the Cepheids from the proper-motions of but eleven of them.

With these considerations in mind, Dr. Wilson made during the past year a survey of all the positional data available for stars of this class, including the San Luis and Albany unpublished observations. This survey resulted in the determination of the proper-motions of 73 stars, to which were added 11 recently determined elsewhere. Investigation of the material showed that for a discussion of the distances of stars with as small apparent motions as those exhibited by the Cepheids, only the better material could be used, as there appeared a marked dependence of the apparent motion upon the errors of determination. In the final analysis the proper-motions of 55 stars were used. The parallaxes derived from the correlation of the proper-motion and radial-velocity data for different period groups closely paralleled those derived by Shapley. It was shown that there is no evidence of an error in Shapley's system of parallaxes exceeding 40 per cent, in contrast to the seven or eight fold increase demanded by other investigators, and that the most probable correction indicated by the material under discussion is in the nature of an increase of approximately 30 per cent. If we accept the deductions based upon the relative magnitudes of the cluster and noncluster Cepheids, we must conclude that the diameter of the stellar system is somewhere between 200,000 and 250,000 light-years.

PROPER-MOTIONS OF THE LONG-PERIOD VARIABLES.

In last year's report were given certain conclusions based upon an investigation of the proper-motions of 154 red stars. Since that time a large amount of additional material has become available, making possible a much more thorough discussion of the motions, mean distances, and luminosities of these stars. As the great majority of them are variables, the scope of the investigation was enlarged to include all the long-period variables. The proper-motions of about 400 of these stars have been determined by Dr. Wilson during the year. An analysis of the motions by types shows that the stars of Class N present in their motions peculiarities which may in part be real but which are shown to be due in part, at least, to their peculiar distribution in the sky. Excluding those of Class N, the remaining 302 stars give as the position of the apex of solar motion:

$$A = 275^{\circ}.5, \qquad D = +31^{\circ}.7$$

in fair agreement with that indicated by the stars in general. Solutions for preferential motion show that these stars follow closely the tendencies of stars of other types in preferential motion towards Kapteyn's vertex, the velocity figure being flattened toward the plane of the Milky Way.

From the mean parallaxes derived by correlation of the proper-motion and radial-velocity data, the following estimates of the mean absolute magnitudes of the stars of the separate spectral classes were made:

Spec.	M	No.	Spec.	M	No.
Misc. F, G, K	+0.4	44 var.	Pec.	+0.3	6 var.
Ma	+0.4	11 var.	S	+0.1	14
Mb	+0.3	24 var.	R	−1.6	15
Mc	+0.2	26 var.	Na	−1.4	16
Mabc	+0.3	61 var.	Nb	−2.4	52
Md	±0.0	89 var.	Np	−4.2	9

The tabulation indicates that, at maximum certainly, the long-period variables must be classified as giant stars; that in those classes composed wholly of stars whose light is subject to large variations there is a very small range of mean absolute magnitude; and that the stars of Classes R and N, composed of stars whose light is either apparently constant or subject to comparatively small variations, are definitely more luminous, a conclusion in harmony with the spectrographic evidence that these stars form a branch of the curve of stellar evolution independent of that of the G, K, and M stars. These results, in conjunction with those derived elsewhere for the non-variable stars, indicate that there is no great range in mean luminosity for the giant stars of types ranging all the way from F5 to S. If from this we are permitted to reason that there can not be a great range in luminosity among the individual stars within each class, the apparent magnitudes may be taken as measures of distance. Comparisons of the parallaxes computed on this assumption with available trigonometric parallaxes indicate that this assumption is not unreasonable for the stars of the M classes.

VELOCITY DISTRIBUTION.

A part of the preparation of a paper, *On the Real Motions of the Stars*,[1] by Benjamin Boss, Harry Raymond, and Ralph E. Wilson, falls within this year's report. Aside from the conclusions noted in previous reports, attention might be called to the expression of the unequal distribution of velocity directions of high-velocity stars as a skewness of the velocity distribution pervading the motions of all classes of stars. The axis of greatest skewness lies approximately in the Galactic plane in longitude 45° to 225°, the large motions avoiding the former direction and preferring the latter.

An attempt was made by Mr. Raymond to separate the skew distribution, as projected upon the Galactic plane, into two Gaussian distributions, either circular (two-stream) or elliptical (double-ellipsoidal), using Akesson's method.[2] The distribution did not satisfy Akesson's criterion, and therefore its skewness can not be explained by such a mixture. If actually due to a combination of distributions, there must be more than two of them, or else one of them at least must be skew; there is, therefore, no point in resolving it.

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[1] Astronomical Journal, No. 820.

[2] On the dissection of correlation surfaces, Lund Meddelande, No. 73.

The skewness explains a number of difficulties relating to stellar motions. For example, it is found that the solar motion derived from stars of large velocity is greater than that derived from the low-velocity stars. This results from the juxtaposition of the axis of greatest excess and the antapex of solar motion. Since it does not coincide with the antapex, the direction of the solar motion will be shifted when derived from small or large velocities, the latter tending toward the point whose galactic coordinates are $L=45°$ and $B=0°$. The principle that the solar motion derived from proper-motions is proportional to the mean parallax must, therefore, be applied with caution. The determination of the direction of preferential motion will also be affected. Consequently, determinations of either solar or preferential motion based upon proper-motions and upon radial velocities, respectively, will not be strictly comparable, since the radial velocities can be and are assorted beforehand into large and small real motions with but little indetermination, while proper-motions can not. The geometry of the case is such that for small motions the radial-velocity apex should be south of the proper-motion value and north for large motions.

SYSTEMATIC ERRORS OF PROPER-MOTIONS.

Mr. Raymond has investigated Kapteyn's[1] proposed correction of $+1''.30$ times the cosine of the declination to the centennial proper-motions in declination of the *Preliminary General Catalogue.* His study, though incomplete, has gone far enough to show that such an error very probably exists, but that its value is only about a third that assigned by Kapteyn.

Three methods of approach at once suggest themselves. One is through a comparison of the results for solar motion derived from proper-motions with those based on radial velocities, from which such corrections may be devised as will force an agreement in the declination of the apex. The second depends on the use of landmarks, which can be regarded as fixed or whose motions may be determined beforehand, and which can be compared with the stars. Such are the declinations of the planets, whose deviations from the tables will be zero in the long run, or the latitude of a fixed observatory, the changes of which are determinable. For the third we may have recourse to meridian observations.

With regard to the first alternative, as is shown from the investigation of velocity distribution, perfect agreement is not to be expected because of skewness, not to mention possible source of error in the radial velocities. The quantity proposed by Kapteyn is at least twice too large for the correction required to bring Boss's determination of the declination of the apex from $+34°$ to $+25°$. The correction derived from small proper-motions amounts to $+0''.65$. For the larger motions there are no good radial-velocity determinations of the Sun's apex, but real-motion results indicate about $+45°$ as against Boss's value of $+34°.5$. Using this data, the correction becomes $-7''$. This illustrates the effect of skew distribution.

To illustrate the second method, two results by others may be set down for comparison. Lambert, in an analysis of the latitudes of the International Latitude stations, obtains a correction of $+0''.55$ to Cohn's motions, which, combined with Schlesinger's computation of Cohn *minus Preliminary General*

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[1] Bulletin Astronomical Institute of the Netherlands, No. 17.

Catalogue = +0″.87 gives a negative correction to *Preliminary General Catalogue.* Only a few stars are common to Cohn and *Preliminary General Catalogue*, however; so this result has trifling weight. Such as it is, it applies to declination +39°, the latitude of the international stations, but, as will appear, the correction there is at least as great as at the equator. Newcomb found +0″.42 from the declinations of the planets as the correction to the Northern Boundary Catalogue, which is corrected +0″.25 by *Preliminary General Catalogue* in the belt from +25° to −24°. This leaves a correction of +0″.17 to *Preliminary General Catalogue.*

The solution of the question rests, in the last analysis, upon meridian observations. It seems natural to suppose that at an observatory where declinations are measured on the same plan, with the same instrument, and reduced in the same manner over a period of many years, the systematic errors would remain sensibly constant, and therefore the motions would not be affected by them. The results do not substantiate this reasonable expectation. In the first place, at no station has there been any such consistency for a long enough time. The nearest approximations are found at Greenwich, Pulkova, and the Cape.

An examination of the observations with reference to this problem can conveniently be made through the systematic corrections to declination dependent on declination as given in the *Preliminary General Catalogue*, supplemented by Mr. Roy's derivation of the systematic corrections to the more recent catalogues. In addition, corrections for Cape 1914 are to be found in the introduction, and Mr. Raymond has determined those of the Pulkova 1915 catalogue of declinations. According to these, Greenwich in the Pond period gave corrections to the *Preliminary General Catalogue* of about a second at the equator. In the intermediate periods this fell to a small and sometimes negative value, and in 1910 changed back to a value of about +0″.5. These observations do not, therefore, give a straight line when plotted with the time as an argument. The other series show similar peculiarities, only less striking. These variations seem to be due largely to changes of methods, particularly in the use of the refraction with which the observations are reduced. Indeed, the major anomalies can be confidently ascribed to refraction. Pond used Bradley's refraction constant, Airy changed to Bessel's second value, that of the *Tabulæ Regiomontanæ*, which is much larger, and this was used, except for 1872, until recently, when the 1910 catalogue was reduced with the Pulkova refractions.

Correcting for these changes, the agreement is greatly improved. The mean of the three series indicates corrections to centennial proper-motions in declination of the order of 0″.4 near the equator. Pulkova gives +0″.6 or 0″.7, Greenwich about half as much, and Cape less than +0″.1. The correction does not follow the cosine of the declination. Its maxima are about +0″.6 at or near declination +30° and −30°, with smaller values between and tapering rapidly to the polar regions, where it is small.

Mr. Raymond has also begun to treat some more recent catalogues in pairs according to the method outlined by L. Boss in *Astronomical Journal*, No. 23, p. 119. This work has gone far enough to indicate that the large positive corrections to the declinations of the *Preliminary General Catalogue*, given by some of the recent catalogues, are due in a measure to refraction. The correction to the centennial proper-motion in declination will probably be of the same order of magnitude as that derived from the study of Greenwich, Pulkova, and the Cape. Many cases may be cited where the refraction that reconciles observations above and below pole will, if used for the equatorial stars, give very anomalous results. Odessa 1910, observed especially for refraction determination, corrects all the standard catalogues by a second or two at the equator, increasing southward. The anomalous nature of the result is shown by the fact that the sun observations stand out from the tables by like amounts. These anomalies are of the kind to be expected if the observations are affected by differential refraction.

This investigation, which is still proceeding, is not expected to give definite corrections to the *Preliminary General Catalogue.* Such a determination must naturally wait for the completion of the reductions of the San Luis and Albany observations, which were especially designed for the solution of this question, among others. It is to be regarded as reconnaissance work. The revision of the *Preliminary General Catalogue* can be more intelligently planned if such work is done in advance.

Mr. Varnum has arrived at similar results in quite a different way. Employing the systematic corrections to forty catalogues as given in the *Preliminary General Catalogue,* he applied a formula of the form $C + at + bt^2$, both in right ascension and declination. The derived corrections in declination agree very closely with those obtained by Mr. Raymond from other considerations. The second-order term was introduced because of the failure of the linear term to fit the observations. Its significance is not clear, but, as has been pointed out by Mr. Raymond, part of the effect may be due to the different refractions used.

When the derived corrections are applied to the solution for solar motion, the apex is placed at $A = 271\overset{\circ}{.}2$, $D = +26\overset{\circ}{.}7$, in harmony with the apex determined from radial velocities and that obtained from the space motions of the stars with velocities under 80 kilometers per second. The mean parallactic motion is reduced from $3\overset{\prime\prime}{.}85$ to $3\overset{\prime\prime}{.}53$. The corrections to the positions in the *Preliminary General Catalogue* are in the direction indicated by Mr. Roy's discussion of the systematic errors of catalogues published since the formation of the *Preliminary General Catalogue.*

The correction to Newcomb's equinox for 1908 derived from Mr. Varnum's discussion amounts to $-0\overset{s}{.}057$, in very good agreement with the recent values derived from observations: $-0\overset{s}{.}052$ by Eichelberger for the 1908 Washington catalogue, and $-0\overset{s}{.}068$ by Hough for the 1908 Cape catalogue. Dr. Lambert[1] finds a correction of $+0\overset{\prime\prime}{.}0048$ to the annual proper-motions of the *Preliminary General Catalogue* in declination +39°. Mr. Varnum derives the value, $+0\overset{\prime\prime}{.}0043$.

DIFFERENTIAL REFRACTION IN ECLIPSES.

In order to illustrate the possible effect of differential refraction at the time of an eclipse, Mr. Varnum has computed the displacement which might be expected at Albany under the same atmospheric conditions that existed at Wallal during the eclipse of September 21, 1922. The resulting value of $+1\overset{\prime\prime}{.}82$ justifies a more serious consideration of the part played by differential refraction at the time of total solar eclipse.

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[1] Special Publications of the U. S. Coast and Geodetic Survey, No. 80.

STELLAR WAVE-LENGTHS.

The relation between the K-term in the B-type stars and wave-lengths is still under investigation by Dr. Albrecht. Although the wave-lengths of silicon by Crooks would entirely remove their proportionate share of the K-term, they are unsatisfactory because of the very large internal discordance between results from the individual lines. In response to an appeal for additional laboratory study, new wave-lengths of silicon have been determined by Mr. Barrell from measures by Professor Fowler and himself. The new values, which are in fairly good internal agreement with stellar wave-lengths, give radial velocities which are systematically 1.9 km. smaller than those obtained with the wave-lengths generally employed in radial-velocity determinations.

For the accurate determination of correlations between stellar wave-lengths, spectral types, and absolute magnitudes it was found highly desirable to reduce the basic data to a much more nearly homogeneous system than was available in the preliminary study of the problem. For this purpose the original reduction sheets for the measures of Palmer, Wright, and Albrecht in *Publications of the Lick Observatory* (vol. IX, part IV) were kindly made available by Professor Wright and Director Campbell. All of the reduction tables and original measures are being rediscussed practically anew, due to the presence in them of numerous inaccuracies which, although affecting the mean radial velocities for the plates very little, do affect the observed wave-lengths of the individual lines quite appreciably, in both an accidental and a systematic sense. The reduction tables have been entirely recomputed and about three-fourths of the new reductions completed.

MOUNT WILSON OBSERVATORY.

George E. Hale, Honorary Director.
Walter S. Adams, Director.

The announcement on July 1 of the resignation of Dr. Hale as Director of the Observatory was received with deep regret by everyone associated in any way with its activities. The entire conception of the Observatory, its development, the scope of its scientific research, its equipment, and methods of investigation are to so large an extent a direct product of Dr. Hale's foresight and his ability in the organization and conduct of research that any change in his relationship to the Observatory is necessarily a matter for profound concern. Fortunately, through a division of the responsibilities connected with its administration, the Observatory will continue to receive the most vital portion of the contribution which Dr. Hale has made to its progress and success during the years of its existence. Although the condition of his health requires him to lay down the burden of the direct conduct of the operative side of the Observatory, he will, as Honorary Director, retain his former relationship to all matters of general policy, the problems of research, and the development of new methods and new instruments. Of more importance than all else to the members of the staff will be the continuance of his personal influence and the inspiration afforded by his broad and active interest in every form of scientific investigation.

The Observatory has profited greatly during the year from the visits of its Research Associates, Dr. A. A. Michelson and Dr. Henry Norris Russell, and from its close relationship with the California Institute of Technology and the scientists permanently or temporarily associated with it. Especial reference should be made to the opportunity afforded to the members of the staff to attend the series of lectures on atomic structure and the quantum theory of spectral lines given during the winter at the California Institute by Professor Sommerfeld of Munich. The intimate connection of many of the investigations carried on in our physical laboratory, especially the temperature classification of spectral lines by King and studies of the Zeeman effect by Babcock, was brought out very clearly in these lectures. This was emphasized even more fully by Russell, who, in the course of a series of informal lectures to the members of the staff, showed how essential to the solution of fundamental problems of series relationships in spectra is a knowledge of the behavior of lines in the electric furnace, in the magnetic field in sun-spots, and in stellar spectra. This close interrelationship of many of the different branches of its work has been a marked feature in the scientific progress of the Observatory.

The preparations for the total solar eclipse of September 10, 1923, have occupied much of the time of the scientific staff during the spring and summer months, and the design and construction of the apparatus have been the chief activity of the drafting department and the instrument shop during this time. The favorable conditions under which the eclipse occurs, at a season of the year and a time of day when clear skies may be expected, and with the edge of the shadow path within less than 30 miles from Mount Wilson, have led to the preparation of an unusually extensive plan for observations. Its principal features are: first, the selection of sites for two expeditions, one at Point Loma, near San Diego, well within the path of totality, and the other at Lakeside, close to the edge of the path; second, the use of the large interferometer frame and polar axis as a mounting for the instruments to be employed at the central station. Reference was made in the last annual report to the 50-foot interferometer telescope designed by Hale and Pease for an extension of the work upon the measurement of star diameters. The central section of the 50-foot beam, which is mounted upon a polar axis and moved by a large driving-clock, makes an excellent support for the long camera tubes, spectrographs, interferometers, and other apparatus which will be used at the eclipse. All of these instruments will thus be pointed directly at the sun and the use of cœlostats or other reflecting devices will be avoided. Through the kindness of the Chief of Coast Artillery, permission has been received to erect this mounting within the military reservation at Fort Rosecrans, Point Loma, where excellent transportation facilities are available and where local observations give good reason to expect favorable weather conditions.

Before we turn to a consideration of the scientific work of the year, attention should be called to the important progress which has been made in connection with the ruling-engine and the promise which this yields of securing large diffraction gratings, not only of excellent quality but also of exceptional brightness in any desired order. It would be difficult to mention any single advance of an instrumental character which could contribute in a more important way to the success of many of our instruments. The powerful spectrographs in use on the sun under present conditions necessitate exposure times which are longer than they should be for the best results on the finer details of sun-spots or the bright lines of the chromosphere. This is even more true in the case of the grating spectroheliograph, and numerous attempts to secure large prisms have shown the great difficulties encountered by the manufacturers of optical glass in securing material suitable for this purpose. The large ruling-engine which has been under construction in our instrument shop for several years is now beginning to yield results which appear certain to improve this situation very materially. After overcoming the numerous obstacles inherent in the construction of an engine of this size in which the mechanical requirements are so exacting, our instrument maker, Mr. Jacomini, who, with the advice and assistance of Dr. Anderson, has had the entire charge of the building of the engine and its adjustment, has succeeded in ruling several gratings of good quality and remarkable brightness in certain orders. This result has been secured through the remarkable success which Mr. Jacomini has attained in the grinding of diamond points to the angle required to concentrate light in any specified order. The angles may be computed readily, but it is only very rarely that natural diamond points can be found with angles approaching these values. By the use of a simple grinding-machine designed for this purpose, it has been found possible to shape diamonds to the required form quickly and accurately. Such diamond points are found to be much more free from irregularities than are the natural points, and as a result are considerably more durable on the average. Among the plane gratings which have already been made are several with ruled surfaces 13 by 8 cm., in which an especial attempt has been made to concentrate the brightness in either the first or the second order. One of these which has been tested in the 75-foot spectrograph of the 150-foot tower telescope permits a reduction in exposure time to one-twelfth that necessary with the excellent grating previously in use. It is with much anticipation and hope that the Observatory looks forward to the results to be attained from the use of the products of this successful ruling-engine.

STAFF.

Dr. George E. Hale, who has been abroad during the year for a rest necessitated by illness, resigned the Directorship on July 1. He has been appointed Honorary Director and will retain his previous relationship to problems of research and all matters of general policy. Dr. Walter S. Adams was appointed Director in charge of operations on July 1 and will continue his investigations in stellar spectroscopy.

Professor Frederick H. Seares, editor of the Observatory publications and superintendent of the Computing Division, has been engaged in researches in stellar photometry and related subjects. Dr. Arthur S. King, superintendent of the Physical Laboratory, has continued his studies of spectra produced in the electric furnace and the applications of ionization phenomena. Dr. Charles E. St. John's investigations have dealt with measurements of wave-lengths in the sun and arc and the solar rotation. Dr. J. A. Anderson has extended his studies of the spectra of explosive discharges and has carried on tests of the diffraction gratings ruled by Mr. Jacomini. Mr. Harold D. Babcock has completed his researches on the Zeeman effect for several elements and has measured wave-lengths in the laboratory with interference apparatus. Mr. Francis G. Pease has continued measurements of the diameters of stars with the 20-foot interferometer and has devoted much time to the design of apparatus, especially that to be used at the solar eclipse. Dr. Paul W. Merrill has completed his investigation of the radial velocities of the long-period variables and is making a study of the physical characteristics of their spectra. Dr. Adriaan van Maanen has been engaged in measurements of the parallaxes and proper motions of stars and of the internal motions in spiral nebulæ. Professor Alfred H. Joy, secretary of the Observatory, has continued his determinations of radial velocity and spectroscopic parallaxes and has made special studies of the spectra of certain variable stars. Dr. Gustav Strömberg has carried on investigations of stellar motions in space. Dr. Seth B. Nicholson has been engaged in solar investigations and measurements of stellar and planetary radiation with thermo-couples. Mr. Ferdinand Ellerman has continued solar observations and has remained in charge of the general photographic work of the Observatory. Dr. Roscoe F. Sanford has completed his measurements of the radial velocities of R-type stars and has determined the orbits of several spectroscopic binaries. Dr. Edwin Hubble has made a study of the forms of nebulæ for the purpose of classification and has extended his researches on the source of luminosity in nebulæ. Dr. Edison Pettit has made solar observations and measurements of solar, stellar, and planetary radiation with thermo-couples. Mr. Milton L. Humason has continued the study of the spectra and radial velocities of the stars in the Selected Areas and has made direct photographs of numerous nebulæ and other objects. Mr. Wendell P. Hoge, night assistant with the 60-inch telescope, has shared in the stellar spectroscopic work. Mr. Joseph P. Hickox has carried on solar observations and has assisted in general photography. Mr. Hickox resigned on July 1 and Mr. Lewis H. Humason was appointed to his position. Mr. Sinclair Smith has assisted in the laboratory and has carried on studies of the spectrum of exploded wires. He has also aided Dr. Michelson in his investigations. Mr. John L. Ridgway has been connected with the staff during several months of the year, and has been engaged in making drawings of sun-spots, showing their positions, polarities, and field-strengths.

In the Computing Division, Miss Mayberry has been engaged in the measurement of the wave-lengths of lines in the spectrum of sun-spots in connection with Dr. Hale's solar investigations. Miss Ware and Mr. Edward F. Adams have assisted Dr. St. John in the determination of wave-lengths of solar lines and of the solar rotation. Miss Joyner and Miss Richmond have been associated with the photometric studies of Professor Seares, and Mrs. Marsh has aided Dr. van Maanen in his observations of the parallaxes and proper motions of stars. The measurement and reduction of stellar spectrograms have been carried on by Miss Brayton, Miss Burwell, Miss Fretz, Miss Poole, and Miss Wiberg. Miss Brayton has also assisted in the reduction of the measurements of stellar radiation. Miss Shumway resigned her position on September 1 after 12 years of service in this department of the Observatory. Miss Keener has devoted all of her time to the work of the Physical Laboratory. Miss Connor has remained in charge of the library and has assisted in much of the editorial work.

Dr. Knut Lundmark, of the Observatory of Upsala, who came to the Observatory as a volunteer assistant on June 1, 1922, remained until May 1 of the present year. He carried on numerous investigations on the color indices of the spiral nebulæ and of faint stars, the distribution of novæ, and related problems. Mr. John A. Carroll, Isaac Newton student of Cambridge University and Research Fellow in Physics in the Norman Bridge Laboratory of the California Institute of Technology, has carried on certain investigations in the Physical Laboratory dealing with the absorption spectrum of hydrogen. Mr. H. H. Plaskett, of the Dominion Astrophysical Observatory, spent the month of June at the Observatory. Professor I. Yamamoto, of the Observatory of Kyoto, became a volunteer assistant in July 1923 and has been engaged in solar investigations.

Dr. A. A. Michelson, of the University of Chicago, Research Associate, spent the period between June 15 and August 15 at the Observatory and has continued his investigation of the velocity of light. Dr. Henry Norris Russell, of Princeton University, Research Associate, passed the months of May and June in Pasadena and was engaged in several investigations, including series relationships in spectra, the masses of stars, and pressure in the solar atmosphere.

The appointment of Professor J. H. Jeans as Research Associate from December 1, 1922, is a matter of the deepest interest to the Observatory. The opportunity to secure the benefit of his wide knowledge of the problems of cosmogony and stellar dynamics is proving of the greatest value to the members of our scientific staff.

OUTLINE OF THE YEAR'S WORK.

The scientific activities of the Observatory have been continued throughout the year with results of marked interest and importance in every department of work. Among these, reference may be made to Anderson's extension of his method of wire explosions, to his use of the vacuum spark, and to the new series of spectra of elements found in this way; the discovery by Strömberg that the asymmetry found to exist in the velocity-distribution of stars is a special case of a more general phenomenon which applies to all celestial objects, including the globular star-clusters and the spiral nebulæ; the investigation of Seares on the luminosity and density functions of stars; the further results of van Maanen on the internal motions of spiral nebulæ and the strong evidence they afford of rotation or motion outward along the spiral arms, in excellent agreement with the theoretical work of Jeans; the extension of the method of spectroscopic parallax determinations to the helium stars and the improvements made in the treatment of those of later types; the discovery by Hubble of a new Magellanic cloud, and his application of his theory of the source of luminosity to the non-galactic nebulæ; the continued successful use of the thermo-couple in measurements of the heat radiation of the stars and planets by Pettit and Nicholson; studies of the masses of stars by Russell; the investigations of Merrill on the spectra of the Me-type stars, and of Joy and Sanford on the spectra of many other variables and spectroscopic binaries; the work of King on the temperature classification of the spectral lines of numerous elements and on ionization effects in the electric furnace; the determination by Babcock from the Zeeman effect of the ratio of the charge on the electron to its mass; and the progress made by St. John in his important studies of the displacements of lines in the spectrum of the center and the limb of the sun, pressures in the solar atmosphere, and the shift of spectral lines required by the theory of relativity. Many of these investigations are in continuation of those made in recent years, and all of them have a direct bearing on the larger problems toward the solution of which the Observatory has been working.

Several extensive investigations, which have been in progress during recent years, have now been brought to a conclusion or have reached the limit set by the observational material at present available. To the first category belongs the great investigation by Seares of the photographic magnitudes of the stars in Kapteyn's Selected Areas. This work, which was begun 13 years ago, has involved a complete study of the methods of photographic photometry as applied to a large reflecting telescope, a revision of the magnitude scale, the determination of standard magnitudes in 139 areas, and finally the measurement of position and magnitude for about 60,000 stars. The completion of this undertaking places at the disposal of astronomers a fund of material applicable to many problems relating to the laws of stellar distribution and luminosity, and marks a notable stage of progress toward the realization of the plans of the great astronomer to whom the conception of the plan of the Selected Areas is due.

Three other investigations which may be regarded as brought to completion for the present are those of van Maanen on the internal motions in spiral nebulæ; of Merrill on the radial velocities of the long-period variable stars; and of Babcock on the Zeeman effect for the elements iron, vanadium, and chromium. Further studies of the motions in spiral nebulæ must await the accumulation of photographs separated by an adequate interval of time, and the results of Merrill and Babcock are so nearly complete for the material at their disposal that few additions may be expected in the immediate future. With this completion of the observational data, the chief importance of further work will consist in the application of the results to physical problems among the stars and in the laboratory.

Somewhat similar in character to these researches is the list of the radial velocities of 1,013 stars published by Adams and Joy. These values represent the product of the observations of several years and form a part of the general program of the stellar spectroscopic department. The material contained in this list has been utilized in a wide variety of investigations, including those by Strömberg on space-motions, the relationship of absolute magnitude to velocity, the study by Seares of the equipartition of energy, and determinations of mean parallax from peculiar motion. The chief value to astronomers of these results consists in the number of faint stars, mainly of the dwarf class, concerning whose motions little has been known hitherto.

OBSERVING CONDITIONS.

The observing conditions at night during the year were nearly normal. Although the precipitation was considerably below the average, the amount of cloudiness varied but little from that of the mean for the past 11 years. The precipitation for the year was 23.81 inches, as against an average value for 19 years of 34.24 inches. The total snowfall was 49 inches. The mean temperature for the year was 54.5°, the highest temperature 94° on June 29, and the lowest 15° on February 1. The average wind velocity was 9.7 miles an hour.

The following table taken from the records for the 60-inch reflector shows the distribution of observing weather with this instrument:

Month.	Hours darkness.	Hours of observing weather.	Hours cloudy.	Observed.		
				All night.	Part of night.	None.
1922						
September	295	230	65	21	5	4
October	336	257	79	22	6	3
November	330	128	202	8	11	11
December	346	109	237	7	8	16
1923						
January	346	182	164	13	9	9
February	308	158	150	10	10	8
March	324	160	164	11	11	9
April	286	140	146	10	8	12
May	266	207	59	18	11	2
June	230	207	23	21	7	2
July	255	217	38	24	5	2
August	269	237	32	25	4	2
Total	3,591	2,232	1,359	190	95	80
Mean for 11 years	....	2,285	1,305	193	90	82

During the year, 2,609 persons used the 60-inch telescope on public nights and over 12,000 visited the museum and inspected the 100-inch reflector during daylight hours. These data are taken from the meteorological and other records maintained regularly by Hoge on Mount Wilson.

SOLAR RESEARCH.

The solar activity has been very low throughout the year and the large number of days on which no spots have been observed indicates the approach of the sun-spot minimum. This absence of spot groups and disturbed areas on the sun's surface has led us to undertake an additional series of observations for the determination of the constants of the general magnetic field. It is also favorable for such investigations as the solar rotation and the displacements of the lines of the solar spectrum upon which the influence of great solar disturbances may be very serious.

SOLAR PHOTOGRAPHY.

Direct photography of the sun and observations with the spectroheliograph have been continued regularly with the 60-foot tower telescope by Ellerman, Nicholson, Pettit, Hickox, and L. H. Humason. During the year ending August 31, 1923, the following photographs have been obtained:

Photoheliograms of 6.5-inch image, 279 on 279 days.
Spectroheliograms of 6.5-inch image with 5-foot spectroheliograph in Hα light, 153 on 153 days.
Spectroheliograms of 2-inch image and prominences and portions of 6.5-inch image, with 13-foot spectroheliograph in K and Hα light and light from continuous spectrum, 747 on 262 days.

The Snow telescope and the 150-foot tower telescope have been used entirely for spectrographic observations.

SUN-SPOT ACTIVITY.

The number of sun-spot groups observed during the calendar year 1922 was 78, as compared with 140 in 1921, 168 in 1920, and 295 in 1919. Of these, 46 were in northern and 32 in southern latitudes. No spots were visible at the time of observation on 111 days, including intervals of 13 consecutive days in April, 13 in May (with 3 days of no observations adjoining), and 16 in August. The recorded number of spotless days would undoubtedly be larger were it not for several cloudy days which occurred at times of solar quiescence. In 1921 there were 31 spotless days and in 1920 only 8. In 1922 the sun was observed on 309 days. The average number of groups observed each day was as follows:

Month.	Daily number.		Month.	Daily number.	
	1921	1922		1921	1922
January	2.7	1.3	August	2.0	0.5
February	2.6	2.1	September	1.8	0.6
March	2.5	3.0	October	1.8	0.9
April	2.8	1.4	November	1.4	0.8
May	1.4	0.6	December	1.8	1.4
June	3.0	0.8			
July	3.5	1.1	Yearly av.	2.3	1.2

The average latitude for the year was 9.2°, as compared with 10° in 1921, 11° in 1920, and 12° in 1919.

SUN-SPOT POLARITIES.

As in previous years, drawings of sun-spots have been made daily at the 150-foot tower telescope, showing their positions, polarities, and field-strengths. The following table summarizes the results of these observations:

Hemisphere.	Polarity.		
	Regular.	Irregular.	Undetermined.
North..........	37	4	4
South..........	24	1	8
Whole sun......	61	5	12

In the last annual report attention was called to a high-latitude spot which was considered as a possible forerunner of the next sun-spot cycle. Three more high-latitude spots have since been observed, one in September 1922, one in June 1923, and one in July 1923. The September spot was at 29° north latitude and was of positive polarity. The flocculi were of such a nature as to make it uncertain whether it was a preceding or a following spot. The spot of June 1923 was also at 29° N. and of positive polarity. This spot, however, was in the following part of the surrounding faculæ and seems to have been a following spot. In that case its polarity was contrary to the regular following spots of the waning cycle. The July spot was at 26° S. and of negative polarity. This was also a following spot and therefore also opposite in polarity to the regular southern spots. Both of these last spots were observed only near the limb, where magnetic observations are difficult. The question of the reversal of polarities at the minimum is therefore still somewhat uncertain. It seems probable that the spots of the new cycle will be reversed in polarity, but this question will not be settled definitely until some bipolar groups have been observed.[1]

All sun-spots observed throughout the year have been classified according to the character of their magnetic fields. The results have been printed every two months in the Publications of the Astronomical Society of the Pacific. Miss Mayberry has assisted in the preparation of these records.

For purposes of reproduction, Mr. Ridgway has continued the preparation of a large number of diagrams taken from the records made with the 150-foot tower telescope, showing the positions and magnetic polarities of sun-spots. It is believed that a satisfactory method of publication has been secured in this way. Mr. Ridgway has also made 15 drawings in great detail of sun-spot groups and several drawings based on enlargements of hydrogen spectroheliograms.

INVISIBLE SUN-SPOTS.

Observations of invisible sun-spots by means of their weak magnetic fields have been continued in the manner outlined in the last annual report. Only three such spots have been located during the year. The small number of such spots is due no doubt to the general low spot activity of the past year.

HYDROGEN ABSORPTION MARKINGS.

At the request of Professor Turner, of Oxford, measures have been made by Miss Ware of the positions and areas of the hydrogen-absorption markings on all Hα spectroheliograms during the period from March to October 1922.

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[1] Subsequent observations of bipolar groups completely confirm the general reversal of the polarity at minimum described by Hale, Ellerman, Nicholson, and Joy in Mount Wilson Contribution, No. 165.

GENERAL MAGNETIC FIELD OF THE SUN.

Three series of plates for determining the constants of the sun's general magnetic field were made in 1914, 1916, and 1920. A fourth series has been completed this year by Ellerman. The series consists of photographs, obtained at the 150-foot tower telescope, of the spectrum in the region λ5247 to λ5329 in the third order of the 75-foot spectrograph with a nicol prism and compound quarter-wave plate over the slit. Six exposures at different latitudes on the central meridian were made on about 40 days at regular intervals during two complete rotation periods of the sun. This series, in connection with those obtained previously, will be used for the determination of a more exact value of the period of revolution of the magnetic pole, and for a study of possible variations in the constants of the sun's magnetic field and their relationship to the phase of sun-spot activity.

SUN-SPOT SPECTRA.

The measurement of the wave-length of lines on photographs of sun-spot spectra taken with the 75-foot spectrograph through a nicol prism and quarter-wave plate has been continued by Miss Mayberry in connection with the investigations of Hale on the strength of the magnetic fields in spots and the displacement of the *p*-component. The region from λ3900 to λ6600 has been completed and more than 11,000 lines have been measured. The discussion of this great amount of material and the comparison of the results with those obtained with the registering microphotometer in the case of close pairs of lines will be the subject of future studies.

SOLAR ROTATION.

The investigation of the period of the sun's rotation through the displacement of the spectral lines has been continued by St. John, assisted by Miss Ware. Especial attention has been given to points in high latitudes. The observations have all been made with the 150-foot tower telescope, and mainly in portions of the spectrum in which atmospheric lines are available for the detection of local solar disturbances. The results show no evidence of a progressive change in the equatorial rotation period from year to year.

WAVE-LENGTHS OF LINES IN THE SOLAR SPECTRUM.

St. John has completed the determination, by means of grating spectrographs, of the wave-lengths upon the international system of several hundred lines in the solar spectrum in the region between λ3650 and λ6750. A comparison of the results with those obtained by Babcock with the interferometer in the region to the red of λ4500 shows such close agreement that full confidence may be placed in the values for the entire list.

CENTER AND LIMB DISPLACEMENTS.

A study of the displacements of lines of the solar spectrum at the limb forms a part of the work which is being carried on by St. John with the 150-foot tower telescope and by Babcock with the Snow telescope and 30-foot spectrograph. From measurements of a selected list of lines supplemented by a few results from the interferometer, Babcock finds a value of 0.0054 A at λ5400 for the mean increase in wave-length at the limb as compared with the center. This displacement seems to increase slowly with the wave-length and depends upon the intensity of the line. The results are in good agreement with those of St. John.

PRESSURE IN THE SOLAR ATMOSPHERE.

St. John has made an investigation of the pressure in the sun's reversing layer from changes in the relative wave-lengths in the sun and arc of lines which belong to groups affected differently by pressure. This makes a severe demand upon the accuracy of the wave-lengths and of the pressure-coefficients per atmosphere, since, to determine fractions of an atmosphere with precision, the ratio of the wave-lengths of lines in the two pressure-groups must be known to a few parts in 10,000,000. A slight change in the adopted values of the pressure-coefficient is sufficient to change the sign of the result. The determination from a single pair of lines is liable to great error and results of value require a large quantity of data.

Other conditions being the same, the use of lines showing great differences in pressure shift would seem to be preferable, but such lines belong, unfortunately, to the very unstable groups c_5 and d, for which the determination is seriously complicated by pole effect in the arc, even under pressures as low as one atmosphere.

Though the difference in pressure coefficient for lines in the comparatively stable groups a and b is small, the precision of its determination and the accuracy of the wave-lengths are so high that the mean from a large number of lines of these groups should give a good idea of the possibilities of the method. The results from the Mount Wilson data are:

Groups.	Region.	No. of lines.	Pressure in sun's atmosphere.
a and *b*	λ3800	41	−1.0 atm.
a and *b*	5050	92	+1.0 atm.
b and *d*	4100	62	+0.8 atm.
b and *d*	4550	37	−0.2 atm.

The conclusion from these observations is that the method is too sensitive to slight errors in the data to yield results accurate to fractions of an atmosphere, but that the pressure in the reversing layer is below one atmosphere and probably in the neighborhood of zero.

The method assumes that effects depending upon wave-length are eliminated by using pairs of lines in the same spectral region. While this would be true for gravitational displacement, it does not eliminate the effects of radial motion unless the levels of effective absorption are the same. It is possible, and, in fact, probable, that the results are influenced by radial motions varying from level to level, and that more consistent results would be obtained by closer attention to level.

An effect which bears upon this result is the increase of ionization over faculæ, shown by the increased intensity of enhanced lines. If the amount of this effect is interpreted by means of an ionization-pressure-temperature diagram based upon Saha's tables, a probable partial pressure somewhat less than 10^{-3} atmospheres is indicated.

RADIOMETRIC OBSERVATIONS OF THE SUN.

The sensitive types of thermo-couples used in measurements of stellar radiation have been employed by Pettit in observations of the sun's radiation, mainly for the purpose of determining the transmission of the apparatus and of the earth's atmosphere. His results lead to the following conclusions:

(1) The transmission of the water-cell used in the apparatus is sensibly a linear function of the air-mass, varying from 68.3 per cent for air-mass 7 to 72.8 per cent for air-mass unity.

(2) The logarithm of the intensity of the transmitted radiation when plotted as ordinate against air-mass gives a line slightly concave to increasing ordinates, a result in agreement with that found by Abbot from pyrheliometer observations.

(3) The corrections to the absorption of the water-cell for selective absorption at the silvered surfaces of the telescope are negligible for stars of spectral type as early as the sun.

(4) The solar radiation in the region of short wave-lengths is greater than that of Capella, a star of the same spectral type. This result is in agreement with that known from direct comparisons of spectra which show that dwarf stars are bluer than giant stars of the same type.

(5) The consistency with which observations made with the vacuum thermocouple can be repeated, the accuracy with which they can be read, and the possibility of self-registration suggest the use of this instrument for measuring the solar constant.

No radiation work on sun-spots has been attempted, owing to the lack of spots of sufficient size.

FOCAL CHANGES PRODUCED BY TEMPERATURE CHANGES IN CŒLOSTAT MIRRORS.

Further observations have been made by Pettit of the focal changes produced by the cœlostat mirrors in the tower and the Snow horizontal telescopes. It was found that of the seven pairs of plane mirrors used, made of crown glass, pyrex glass, and speculum metal, all became concave when exposed to the sun, with the exception of the speculum mirrors and the crown-glass mirrors of the Snow telescope. This result is difficult of explanation on the present theory of the expansion of mirrors. No material difference was found when a concave mirror in place of a lens was used to project the image. The most rapid changes of focus were observed in the case of crown-glass mirrors 12 inches in diameter and 1 inch thick. In this case the change of focus at the 150-foot tower telescope amounted to 5 meters in 3½ hours. The smallest changes were those with the speculum and pyrex-glass mirrors. With the latter the focus changed 55 cm. during the first hour, but thereafter remained essentially constant during observations extending over 8 hours.

RESEARCHES ON THE MOON AND PLANETS.

THE ROTATION PERIOD OF VENUS.

Reference was made in the last annual report to the possibility of using the spectrograms of Venus obtained at Mount Wilson in a study of the rotation period of the planet and a possible determination of the solar parallax. St. John and Nicholson have completed the necessary measurements and have studied them with reference to these objects. The change in wave-length of lines at the center of the illuminated portion of Venus is a function of the rotation of the planet and the relative orbital velocity of Venus and the earth. Rotation of the planet would produce changes of wave-length which, in the comparatively short interval over which observations are possible, can not be distinguished from the influence of an error in the value of the solar parallax used in correcting for the relative velocity of Venus and the earth.

Differential measures at the limb and terminator can be used to determine the rotation of the planet. Measures of this character give a small negative value for the equatorial velocity of Venus, with a probable error of the same order. It is here assumed that the plane of the planet's equator is in the plane of its orbit. A similar investigation made some years ago by Slipher at the Lowell Observatory also gave a small negative value for the equatorial velocity with a relatively large probable error. It seems very improbable that Venus rotates in a direction opposite to that of the earth and Mars, and if we assume that the rotation is really direct and that the negative values are due to errors of observation, we may interpret the result in the light of its probable error by saying that the chances are about ten to one that the period is longer than 20 days.

It is possible that the equator of Venus is nearly perpendicular to the plane of the planet's orbit. W. H. Pickering has interpreted certain of his observations in this way and has given the position of the axis of rotation. Spectrograms have been taken at favorable times and with orientations of the slit suitable for testing this possibility, but with results which are decidedly against the large inclination of the equatorial plane arrived at by Pickering.

RADIOMETRIC OBSERVATIONS OF THE MOON AND PLANETS.

Pettit and Nicholson have studied the radiation from the moon, Mercury, Jupiter, Saturn, Uranus, Neptune, and the asteroid Vesta with a vacuum thermo-couple having a rock-salt window furnished by Dr. Abbot, of the Smithsonian Astrophysical Observatory. Observations have also been made through the water-cell, which transmits radiation only to 1.3 μ, and through the microscope cover-glass, which transmits to 7 μ in the infra-red. By combining the results and correcting for reflection from the cells the amount of energy which enters our atmosphere through Fowle's transmission band 8 μ to 14 μ can be measured. This quantity, which Pettit and Nicholson have called "planetary radiation," is the radiation emitted by the heated surface of the planet, as distinguished from the general radiation which includes reflected light.

The observations indicate that Jupiter and Saturn emit about 6 per cent of planetary radiation as against 74 per cent from the moon. Drift curves of the moon taken near the first or last quarter show that the total radiation per unit of area of the illuminated portion is proportional to the distance from the limb, being zero at the terminator. The transmission of the water-cell is nearly constant over 70 per cent of the region from the limb to the terminator, and then rises gradually to double its value at the limb. The planetary radiation seems to be nearly the same over the dark areas of the moon as over the brighter portions. In the case of Jupiter, the drift curves show a falling off in total radiation near the limb, as well as in visual light.

Observations of Mercury were made at western elongation on June 17 and 21. The planet was found to emit 74 per cent of planetary radiation, a value identical with that obtained for the moon near the same phase. In addition, the distribution of energy in the three regions, 0.3 μ to 1.3 μ, 1.3 μ to 5.5 μ, and 8 μ to 14 μ, as indicated by the transmission screens, proved to be very similar to that of the moon. These results afford new evidence that the atmosphere of Mercury, like that of the moon, is negligible in amount. The agreement both in spectral distribution of energy and in the amount of planetary radiation emitted by these two bodies per unit of illuminated area leads to the rather surprising conclusion that the temperature of the illuminated surface of Mercury is about the same as that of the moon. This result is best explained by assuming a short period of rotation for Mercury, and some measurements made of the radiation from the dark side of the planet favor this view.

In the case of both Jupiter and Saturn, the measures show that a larger proportion of the radiation is transmitted by the water-cell than in the case of the sun. This is probably due to selective reflection. The radiation from Saturn's rings is essentially reflected sunlight, although the percentage transmitted by the water-cell is somewhat larger.

RESEARCHES ON NEBULÆ.

DIRECT PHOTOGRAPHY.

The direct photography of nebulæ has been continued by Hubble and Humason. Especial attention has been given to dark nebulæ and luminous nebulæ showing dark markings, so many of which were discovered by Barnard with the Bruce telescope. The large scale of the negatives with the 60-inch and 100-inch reflectors has served to bring out a remarkable amount of detail in many of these objects. Such photographs are essential to investigations like those of Hubble on the source of luminosity in nebulæ and of Russell on dust clouds in space and the nature of dark and bright nebulæ.

A study of the extraordinary variety of forms observed among the nebulæ has been made by Hubble with the object of dividing them into groups upon which may be based a definite system of nebular classification. For this purpose he has secured over 100 photographs, most of them of non-galactic objects taken from the list of Holetschek, which had not been photographed previously on an adequate scale. In addition, several of the larger and brighter non-galactic nebulæ have been photographed with the 100-inch telescope. The results of this study have been placed before the members of the Committee on Nebulæ of the International Astronomical Union to serve as a basis for discussion in the formulation of a system of classification.

Hubble has found that the nebula N. G. C. 6822, in which a general resemblance to the Magellanic Clouds had been noted previously, is similar to them in all respects and constitutes a new object of this character. It consists of an irregular cloud of very faint stars, about 16 by 8 minutes in size, in which are involved four patches of diffuse nebulosity, all showing emission spectra, at least 3 planetary nebulæ, and 12 variable stars. Attempts will be made to obtain the radial velocities of some of the nebulæ, the magnitudes and color indices of the brighter stars, and the light curves of the variables.

Most of the photographs of spiral nebulæ required for comparison with earlier photographs of the same objects have been obtained by Humason. Several of these have been used by van Maanen in his measurements of internal motions in spiral nebulæ. For such purposes it is essential that the images be very small and round, a combination frequently difficult to secure in the case of exposures extending over several hours. Some excellent negatives of this character, however, have been obtained with the 100-inch telescope.

Humason has also photographed several planetary nebulæ and a number of miscellaneous objects for purposes of classification.

STUDIES OF LUMINOSITY IN NEBULÆ.

The last annual report summarized the evidence found by Hubble, which indicates that galactic nebulosity derives its luminosity from the radiation of stars associated with it. In diffuse nebulæ, which have either absorption or emission spectra, there is a close quantitative agreement between the amount of light received by the nebulosity from the stars and that emitted by the nebulosity. This relationship does not hold in the case of the planetary nebulæ, the amount of light emitted being considerably greater than that received from the central stars. The discrepancy suggests that the agreement in the case of diffuse nebulæ with bright-line spectra is purely accidental, since the associated stars, in them as in planetaries, have spectra which are predominantly continuous or dark-line in character. The phenomenon, therefore, can not be one of simple reflection of star light. These conclusions are based upon photographic results from ordinary plates, and studies made in the ultra-violet and red portions of the spectrum may assist in the interpretation of the nature of the absorbed and emitted radiation.

Hubble has extended his investigations to individual non-galactic nebulæ, measuring the densities of a series of exposures made on each plate with the Koch recording microphotometer. The work has been confined almost wholly to elliptical nebulæ and the amorphous nuclear regions of a few spirals. Elliptical nebulæ are the wholly amorphous objects ranging from globular to spindle in form, in which the brightness seems to decrease steadily outward from the nucleus. The principal characteristic is rotational symmetry about a dominating semi-stellar nucleus.

Measurements of the density curves along the diameters of about 25 nebulæ show that the results can be represented closely by the formula

$$D = D_0 - 2\log\left(\frac{r}{a}+1\right)$$

where D is the density of the photographic image at a distance r from the center, D_0 is the density at the center, and a is a constant for a particular curve, depending upon the nebula and the diameter along which the curve is constructed. A mean curve may be formed by using r/a as the independent variable and shifting the individual curves along the D-axis into coincidence. The mean residuals over the well-determined portion of this curve are less than 1 per cent. Five curves made from the photovisual images of three nebulæ show the same mean slope as the corresponding curves made from photographic images, a result which suggests that in these nebulæ, at least, scattering is not a conspicuous phenomenon.

Since D is the logarithm of the intensity, the distribution of illumination in the images of these nebulæ is represented by the formula

$$I = \frac{I_0}{\left(\frac{r}{a}+1\right)^2}$$

The central regions of the few spirals which have been observed seem to follow the same general law, and the results suggest that amorphous non-galactic nebulæ are built on a nearly uniform pattern.

INTERNAL MOTIONS IN SPIRAL NEBULÆ.

The principal investigation of this character was the measurement by van Maanen of 400 points in the great spiral nebula Messier 33 on negatives taken in 1910 by Ritchey and 1922 by Humason. The results confirm strongly those obtained from six spirals measured previously in showing the presence of internal motions which can be interpreted either as rotation or as a motion outward along the spiral arms. Further investigations will be deferred until photographs taken with the 100-inch telescope and separated by an adequate interval of time are available.

In summing up the results of this difficult and very important research, mention should be made of the strong character of the evidence which leads us to place full confidence in the values obtained.

(1) Of the seven nebulæ measured, three are left-handed and four right-handed spirals. The photographs measured were obtained for the most part at the primary focus of the 60-inch reflector, but include negatives taken at the Cassegrain focus of this instrument and a few made with the Crossley reflector of the Lick Observatory. None of these photographs shows any displacement for the comparison stars such as is found in the nebulæ.

(2) Measurements of Messier 51 by Kostinsky, Lampland, and Schouten from observations with three other instruments give results similar to those found by van Maanen.

(3) The negatives used by van Maanen were also measured by other observers, in the case of Messier 101 by Nicholson and of Messier 33 by Lundmark, with confirmatory results.

(4) Three different measuring-instruments were used in the course of the work. The same machines, when used in the measurement of proper motions on ordinary star-fields, have never shown any rotary displacements.

From a combination of the results of various methods used in deriving the distances of the larger spirals, it appears that their parallaxes probably lie between a few ten-thousandths and a few thousandths of a second of arc. This would indicate diameters between a few light-years and several hundred light-years.

COLOR INDICES OF SPIRAL NEBULÆ.

Previous to his return to Upsala in May, Dr. Lundmark obtained a considerable number of photographs of nebulæ taken through the large objective grating attached to the 60-inch reflector. These include in particular condensations in the arms of spiral nebulæ, small non-galactic nebulæ, and former novæ. The results will be made the subject of a study of color indices which Lundmark is preparing.

SPECTROSCOPIC OBSERVATIONS OF NEBULÆ.

Most of the spectroscopic observations made during the year have been those of Hubble on the nuclei in planetaries, a few related objects such as N. G. C. 2359 and 6888, and the novæ about which nebulosity has been observed. The detailed discussion of the spectrograms has not been completed, but a simple inspection shows that the planetary nuclei for the most part are normal early-type stars with continuous and absorption spectra which range from O5 to O8 on H. H. Plaskett's classification. N. G. C. 40 and B. D. +30° 3639 are the only cases among the brighter nuclei in which emission bands predominate.

RESEARCHES ON STARS.

TRIGONOMETRIC PARALLAXES AND PROPER MOTIONS.

In continuation of his work on trigonometric parallaxes, van Maanen has obtained during the year 173 photographs with 401 exposures at the 80-foot focus of the 60-inch reflector, and 147 photographs with 263 exposures at the 42-foot (primary) focus of the 100-inch telescope. The plates necessary for the derivation of parallaxes have been secured for 20 fields, thus bringing the total number of completed fields to 180.

Among the objects of especial interest for which parallaxes have been determined are α Orionis and β Andromedæ. The measurement of the diameter of α Orionis by the interferometer method makes an accurate value of its parallax of great importance. Including the Mount Wilson result and the spectroscopic value, six determinations are now available for this star, and the weighted mean, $+0''.017 \pm 0''.002$, is probably one of the most accurate parallaxes known at present. The linear diameter of the star using this value is about 245,000,000 miles.

The star New Draper Catalogue 4143 of M-type spectrum, magnitude 8.8, and a proper motion of $0''.027$ annually was placed on the observing list because of the possibility that it might prove to be an M-type star of absolute magnitude intermediate between the giants and dwarfs. The parallax, however, shows it to be a giant star of absolute magnitude +1.2.

Three stars of very large proper motion discovered by Wolf, Nos. 1037, 1039, and 1040, were observed with the 100-inch reflector. Their parallaxes show them to be dwarf stars of absolute magnitude about 13 on the photographic scale, with linear velocities at right angles to the line of sight of about 110 km. a second.

A very extraordinary result was found in the case of o Ceti, the relative parallax proving to be $-0''.081 \pm 0''.036$. The large negative value and high probable error make it very likely that this result is due to the remarkable asymmetry of the star near minimum of light which was discovered by Adams and Joy from spectroscopic observations and referred to in the annual report for 1921.

Parallaxes have been determined for two of the giant planetary nebulæ, as follows:

Dumbbell Nebula, N. G. C. 6853: $\pi_{\text{rel.}} = +0''.011 \pm 0''.004$.
Helical nebula, N. G. C. 7293: $\pi_{\text{rel.}} = +0''.058 \pm 0''.005$.

These values would give for the absolute magnitudes of the central stars +8.8 and +11.2, respectively, and diameters of 700 and 375 times that of the orbit of Neptune.

The measurement of the proper motions of the comparison stars in the fields of the stars under observation for parallax has been continued by Mrs. Marsh, under the direction of van Maanen, and a total of 30 fields has been completed. Mrs. Marsh has also measured the proper motions of four planetary nebulæ and three faint stars of large proper motion discovered by van Maanen. One of these has an absolute magnitude of +11.3 and appears to be a companion of Pi 5^{h} 146.

STELLAR PHOTOMETRY.

Photographic Magnitudes in the Selected Areas.

With the exception of three fields, the catalogue of magnitudes for Areas 1 to 139 has been practically completed by Seares, with the assistance of Miss Joyner and Miss Richmond. The stars have been counted for half-magnitude intervals, both for the fields measured at Groningen and at Mount Wilson. These fields overlap but do not coincide, and since the limiting magnitudes differ for the two series, it has been necessary to segregate the counts in order that the results may be homogeneous. The totals are subject to some revision, but stand approximately as follows: Mount Wilson, 60,000; Groningen, 40,000.

A detailed statement of the whole investigation, which has extended over several years, has been prepared by Seares. This has appeared as an appendix to the report by Dr. van Rhijn on the status of investigations in the Selected Areas.

The Luminosity Function.

The constants of the luminosity function depend on the formula for mean parallax expressed as a function of proper motion and apparent magnitude. Since the mean-parallax formula has been based in part on the parallactic motions of stars as faint as the eleventh magnitude, it is of interest to know how accurately the luminosity function represents the accumulated data for the stars of the brighter apparent magnitudes whose distances have been measured individually. The density function is also involved, but this depends only on the luminosity function and the observed number of stars in each interval of apparent magnitude, which is subject to no great uncertainty. Seares has made the calculations necessary for a comparison. For the stars brighter than the fifth apparent magnitude the calculated distribution of absolute magnitudes agrees with the observed distribution as well as can be expected in view of the numerous disturbing factors. The chief divergence is an excess in the calculated number of stars of very high luminosity, which may be interpreted as a systematic difference between mean parallaxes and parallaxes measured directly by trigonometric methods. This difference is of the same sign and approximately of the same amount as that brought to light through the recent discussion by van Rhijn.

Unfortunately, the comparison can not be extended satisfactorily to the stars of fainter apparent magnitude, because of the selection in favor of large proper motions and low luminosities, which affects the data on parallaxes of individual stars. This leaves an important point unsettled. It is known that the observed number of stars of low luminosity among those near the sun is in excess of the number calculated from the luminosity function, but the total numbers involved are so small that the divergence can scarcely be accepted as proof of error in the luminosity curve. The comparison in question reproduces the evidence on this point, but does not greatly extend it.

Since important questions depend on the form of the luminosity function, an attempt has been made by another method to test the applicability of the gaussian error curve. It can be shown analytically on the basis of the adopted distribution functions for luminosity, density, and tangential velocity that, very approximately,

$$\overline{M}-H = \text{a linear function of } H, \text{ where } H = m + 5 \log \mu$$

and $\overline{M}$ is the mean absolute magnitude of the stars having the apparent magnitude m and the proper motion μ. This presupposes that the luminosity function has the form of an error curve. If, however, the observed data for stars of known parallax be grouped according to magnitude and proper motion, the following result is found: The differences $\overline{M}-H$ are approximately a linear function of H for $\overline{M}$ less than the sixth absolute magnitude. Beyond $\overline{M}=8$ the relation seems again to be linear. Between these two points the functional relation is more complicated. Beyond the eighth magnitude the linear character is uncertain, but this at least seems definite: about 75 stars of low average luminosity show a definite departure from the linear relation which satisfactorily represents the stars of higher luminosity. This indicates that for stars on the ascending branch of the curve the gaussian curve of Kapteyn and van Rhijn is applicable. For stars on the descending branch, however, another curve is required, which will be gaussian or not according as the differences $\overline{M}-H$ for the fainter stars do or do not bear a linear relation to H.

The method used has the advantage that the data combined are selected and grouped on the basis of proper motion, so that all stars of large proper motion and known parallax can be utilized. The results indicate that the luminosity function is a skew curve with a descending branch that is relatively flat, and that the total number of intrinsically faint stars is much greater than hitherto supposed. At the same time, it must be noted that the conclusion turns on the characteristics of a small number of stars.

STELLAR SPECTROSCOPY.

A three-prism stellar spectrograph designed primarily for photographing the yellow and red portions of the spectrum has been completed during the year and has been used by Merrill in his studies of Me and S type stars. We have also secured a two-prism spectrograph by Hilger, with an optical ratio of 1 to 5, for use at the primary focus of the reflectors in work on the ultra-violet part of the spectrum. These instruments, together with two new camera lenses, an 18-inch triplet by McDowell and a 10-inch lens designed by Moffett, represent the additions made to the instrumental equipment of this department. The low-dispersion spectrograph for use in the plate-holder frame at the Cassegrain focus of the 100-inch reflector, which was referred to in last year's report, has proved to be most useful for work on very faint stars.

A total of 1,366 spectrograms has been obtained during the year with the large Cassegrain spectrographs, 567 with the 100-inch reflector, and 799 with the 60-inch. About 100 others have been secured with the smaller spectrographs, mainly at the primary focus of the two reflectors. The observing program has remained much the same as in recent years, the stars observed with the 100-inch telescope being mainly dwarf stars of large proper motion, faint variables, and the companions of visual binaries, while the list for the 60-inch reflector is made up principally of the stars from the Preliminary General Catalogue of Boss and numerous double stars taken from Russell's list of dynamical parallaxes.

RADIAL VELOCITIES.

The catalogue of the radial velocities of 1,013 stars by Adams and Joy, to which reference has already been made, constitutes the most extensive publication of this character so far issued by the Observatory. The list comprises stars selected for observation during recent years for a wide variety of reasons, occasionally on the basis of apparent magnitude, but more often because of large or small proper motion, variability, binary character, or some similar characteristic. The composition of the list is related closely to the work upon the spectroscopic determinations of absolute magnitude and parallax, many stars being observed primarily for spectral type and only incidentally for radial velocity. As a consequence, the list is by no means a representative one for stars in general but includes a large excess of giant and dwarf stars.

A sufficient number of stars has been observed in common with the Lick and the Dominion Astrophysical Observatories to make it possible to compare the results for systematic differences. In the case of 109 stars of types F to M observed at the Lick Observatory, the Mount Wilson systematic difference is −0.12 km., the agreement being excellent. Similarly for 83 stars observed in common with the Dominion Astrophysical Observatory, the difference is +0.77 km. In view of the low dispersion used in the spectrographs at Victoria and Mount Wilson, this value may be regarded as satisfactory, although the rather large systematic difference found for stars of type M requires further investigation.

During the past four years Merrill has obtained observations of the radial velocities of 113 long-period variable stars. With the addition of those for which velocities were known previously, a total of 133 stars of types M and S is now available for which radial velocities have been derived from the bright lines. Velocities from the absorption lines have also been measured for 47 of these stars. The relative displacements of the bright lines are found on the average to increase with advancing type, increasing period, and magnitude range. The correlation with period has been used to establish an empirical correction to be applied to the bright-line velocities to reduce them to a dark-line basis. This is essential, since the displacements of the dark lines rather than those of the bright lines appear to correspond to the true radial velocities. The investigation has necessitated the determination of the wave-lengths of numerous bright and dark lines in these spectra.

Studies of the apparent solar motion with respect to these 133 variables show that the speed of the sun is almost three times that usually found for K and M stars, but that the position of the apex is nearly the same. The following values are representative: $A_0 = 281°$; $D_0 = +34°$; $V_0 = 53$ km.; $K = +1$ km.; arithmetic mean residual, 31 km.; 68 stars with residuals less than 25 km. give $V_0 = 48$ km., and 65 with larger residuals, $V_0 = 65$ km. This increase in V_0 furnishes an excellent illustration of the well-known velocity-asymmetry of stars of high speed. The average residual radial velocity is found to decrease with advancing spectral type and increasing period. Very high velocities are confined largely to stars of types M2e and M5e and to stars having periods in the neighborhood of 200 days. These facts are difficult to explain on the basis of any hypothesis of the origin and evolution of red stars which has yet been proposed.

Several stars which were observed over a considerable part of the light curve show a slight variation in the apparent velocity from the emission lines. The velocities appear to have algebraically low velocities for a month or two after maximum of light.

Apart from these two major investigations on radial velocities, reference may be made to the following results obtained in this department of work during the year:

(1) The radial velocities of 192 additional stars have been obtained from three or more spectrograms.

(2) A special series of observations has been carried out on the stars in the cluster of Præsepe. In a total of 34 stars observed, 26 are found from their velocities to belong to the moving cluster, 3 do not belong, and 5 are spectroscopic binaries. The radial velocity of the cluster as determined from these 26 stars is +33 km.

(3) Observations of a number of the fainter variables of the cluster type show that the remarkably large dispersion in radial velocity previously found among stars of this class is present in an even greater degree among its fainter members. Two stars of this character, VX Herculis and RZ Lyræ, show radial velocities of −375 and −280 km. respectively, with probably only a moderate variation.

(4) Several spectroscopic binaries are under investigation by Sanford. For two of these, Lalande 13792 and A. Oe 12584, orbits have been computed and published. Preliminary orbits have been found for four others. From these results and those derived previously, Sanford finds that the evidence indicates shorter periods and smaller eccentricities for dwarf spectroscopic binaries than for giants of the same spectral type.

(5) Sanford has completed the determination of the radial velocities of 30 stars of the R type of spectrum from a total of about 80 spectrograms. All of these have been measured by two different methods, and intercomparisons show that no serious systematic error appears to exist. The range in velocity among these stars is extraordinarily great, one star in the list showing a velocity of −380 km. For this reason, in spite of the comparatively small amount of material, a study of the space-motions of these stars will be of interest in its bearing on the asymmetry of the velocity distribution of stars of rapid motion.

(6) Spectroscopic observations of both components of the unique double star X Ophiuchi have been secured by Merrill, which lead to a reliable value of +0.3 for the absolute magnitude of the variable component when at maximum of light. The importance of this determination lies in the fact that this component is a typical long-period variable, and that the absolute magnitudes of such objects have been derived hitherto only by statistical methods. The apparent radial velocity of the variable (spectral class M6e) is found from the absorption lines to be −70.6 km. and from the emission lines −83.4 km. The velocity of the other component, a giant star of class K0, is −70.8 km., showing that the absorption lines of the variable yield essentially the true radial motion, while the emission lines at maximum are displaced toward shorter wave-lengths by an unknown cause. A systematic variation in the displacements of the bright lines, depending on the light phase, has been detected.

(7) Humason has continued the determination of the radial velocities of the stars in the Selected Areas with the Cassegrain spectrographs. Spectrograms have been obtained of 98 stars, and the velocities of 62 of these have been measured on three or more negatives.

Spectroscopic Determinations of Luminosity and Parallax.

Investigations dealing with the spectroscopic method of deriving parallaxes have been carried on along three principal lines; first, the continuation of the determination of the absolute magnitudes and parallaxes of the stars under observation with the stellar spectrographs; second, an extension of the method to the B-type stars; third, a special study of the giant stars of the K type of spectrum. The work has been in charge of Adams, Joy, and Sanford, with Strömberg taking part in the computations relating to the K-type stars.

Determinations of absolute magnitude for stars of types A, F, G, K, and M have made rapid progress during the year and more than 900 stars, in addition to those already published, are now upon our lists with values of the parallax obtained in this way. For the stars of types F to M we have used the methods of reduction described in connection with the catalogue of 1,646 stars, and for the A-type stars the method derived last year, to which reference was made in the annual report. The stars added during the year include numerous stars of large proper motion, a considerable number of visual binaries which are comprised in Russell's list of dynamical parallaxes and have been observed for this reason, and many stars from the catalogue of Boss. It is evident that the effect of selection, which is very marked in the catalogue of 1,646 stars and makes it far from representative of stars in general, will become much less effective in future lists. In the earlier stages of the investigation of absolute magnitude by spectroscopic methods, the attempt was made to select stars of exceptionally high or low luminosity in order to calibrate the reduction curves over a wide range. With the completion of the reduction system, however, such a selection becomes no longer necessary.

The extension of the method of spectroscopic parallax determinations to the B-type stars depends, as in the case of those of type A, upon the small dispersion in absolute magnitude shown by the stars of this spectral class. By the aid of individual parallaxes obtained directly from trigonometric measurements and from moving clusters, and the use of mean parallaxes derived from the numerous statistical investigations on the helium stars, it has become possible to construct a simple reduction system which gives the absolute magnitude of a B-type star when its spectral class is known accurately. The method is in all respects analogous to that used for the A stars, of which it forms a direct continuation. The stars with sharp lines in their spectra are found to be brighter than those with diffuse lines in all cases except possibly the very early B stars, where the results are uncertain.

The application of the method to 300 stars gives individual values in good agreement with those derived from trigonometric measures or moving clusters. The absolute magnitudes also show an excellent degree of correlation with the reduced proper motion, $0.2\,m + \log \mu$, the curve being very nearly a straight line, except in the case of the stars with extremely small proper motions.

The relatively small dispersion in absolute magnitude among the giant K-type stars given in the catalogue of 1,646 stars might be explained either as an inherent characteristic of these stars or as a result of failure of the lines used in the spectroscopic method to serve as adequate criteria for distinguishing differences of magnitude among such stars. The latter explanation has been advocated by van Rhijn. For the purpose of distinguishing between these alternatives, a special investigation has been made, using as material about 80 stars with excellent trigonometric parallaxes and about 130 other stars of well-known proper motion which have been observed recently. No selection has been made except on the basis of apparent magnitude. Radial velocities are known for many of these stars, so that derivations of mean parallax are possible from peculiar as well as parallactic motions.

A preliminary study of the correlation between the intensity of the principal line used in the spectroscopic study of these stars, the enhanced line of strontium at λ4215, and the reduced proper motion showed an excellent degree of correspondence. On the other hand, the calcium line at λ4455, the intensity of which serves admirably to distinguish between giant and dwarf stars of this type, is found to be comparatively insensitive to differences in absolute magnitude among the giants themselves. This fact has been recognized previously, and low weight has been assigned to it in this class of stars. Two other lines, accordingly, have been selected of a character similar to λ4215, the enhanced strontium line at λ4077 and the enhanced iron line at λ4233, and estimates have been made of their intensities in the spectra of the selected list of stars. These intensities, divided into a number of groups, have then been compared with the mean parallax as derived for each group from trigonometric measures, parallactic motion, and peculiar motion.

The results are conclusive in showing that the intensity of each of these lines is correlated closely with absolute magnitude and serves as an excellent means of deriving its value. They also show the close agreement for these groups of stars of the mean parallaxes derived from trigonometric values on the one hand and parallactic and peculiar motion on the other. The accuracy of the trigonometric parallaxes for these stars, many of which have small proper motions, is thus shown to be quite comparable with that of the values derived by the other two methods. The main conclusion to be drawn from the investigation is that the dispersion in absolute magnitude among the K-type stars is small and that the corrections to be applied to the values published previously are slight.

COMPARISON OF SPECTROSCOPIC AND DYNAMICAL PARALLAXES.

The hypothetical parallaxes of more than 1,600 visual double stars have been calculated by Dr. Russell at Princeton University during recent years, on the assumption that the mass of the system in each case is equal to that of the sun. In order to correct this assumption and obtain dynamical parallaxes based on the actual mean masses of stars of different spectral types, a comparison has been instituted by Russell, Adams, and Joy between the hypothetical values for 327 of these stars and those derived spectroscopically at Mount Wilson.

The stars have been separated into giant and dwarf classes and divided into groups according to spectral type. The interesting result then appears that the relationship between the absolute magnitude M_1 derived from the hypothetical parallax and the ratio s/h_1 of the spectroscopic and hypothetical parallaxes is very nearly linear. All of the groups of stars agree in this result, including the white dwarfs of types A and F. The residuals from the formula

$$s/h_1 = 0.62 + 0.045\ M_1$$

average about 6 per cent of both s and h_1. A similar comparison between s/h_1 and spectral type shows that in this case no simple relationship exists.

The conclusion, therefore, may be drawn that, statistically considered, the mass of a binary system is a function of its absolute magnitude and not of its spectral type.

The results indicate that the spectroscopic absolute magnitudes of the early F-type stars as derived by the method used for the A stars are more nearly correct than the previous values derived mainly by extrapolation from stars of later type. The correction to the latter system is found to be +0.42 magnitude, in agreement with the value +0.5 found by Adams and Joy.

The geometrical mean masses for the different types of stars agree with the values derived by Seares, except for the B and A stars. The difference in these two cases almost certainly is due to the data for the double stars used in the two investigations.

The Space-Velocities of the A-Type Stars.

Strömberg has completed his study of the motions in space of the A-type stars to which reference was made in the last annual report. The chief result of this investigation is the proof of the existence of three groups of stars which differ from one another in their systematic motions. Two of these are to be identified with the well-known Taurus and Ursa Major groups, but the majority of the stars belong to a central group with an ellipsoidal distribution of motions. This central group has the same group-motion but a smaller dispersion in velocities than the ellipsoidal group to which stars of later types belong. The low value of the solar motion as derived from the A-type stars is due to the large proportion of stars which belong to the Ursa Major group.

The Asymmetry in the Distribution of Cosmic Velocities.

The lack of symmetry in the distribution of stellar motions in space has been made the subject of a special investigation by Strömberg. He now finds that this phenomenon, which is especially marked among stars of high velocity, can be traced to all classes of stars and to the globular star-clusters and spiral nebulæ. It shows itself as an increase in the sun's velocity with an increase in the internal velocities of the group of objects to which the solar motion is referred. No star with a space-velocity exceeding 100 km. has yet been found which is moving toward the portion of the sky lying between the limits of galactic longitude −10° and +150°.

The phenomenon appears to be a perfectly general one everywhere in space. As a purely tentative hypothesis and one calculated to promote discussion, Strömberg has suggested the following explanation: If a certain reference system is assumed to exist in space referred to which excessive velocities for some reason do not occur, it can be shown that this "velocity-restriction," in combination with the internal motions of the objects in the different groups, will produce an effect similar to that which is observed. The sun's velocity in this frame of reference will probably be the same as that which is found when it is referred to the spiral nebulæ. This is about 400 km. towards the apex $\alpha = 304°$, $\delta = +81°$. The hypothesis is worthy of consideration as an attempt to explain an extraordinarily far-reaching phenomenon.

The Spectrum of *o* Ceti.

The spectrum of this important variable star has been the subject of a further investigation by Joy. The radial velocity over seven cycles of the star's variation in light shows changes which doubtless have a vital bearing on the interpretation of the behavior of this class of variables. The velocity curve as derived from the absorption lines follows the light curve, the maximum velocity of recession coinciding with maximum of light. The velocity curve from the bright lines, on the other hand, shows a maximum of velocity at minimum light, so that at this phase there is approximate agreement between the velocities derived from the dark and the bright lines.

The asymmetry in the spectrum which was noted in previous years has been investigated by rotating the spectrograph so that the slit would lie at several different position angles. The results indicate that the origin of the peculiar spectrum of broad bright hydrogen and helium lines, with a marked displacement toward the red, is situated at a position angle of about 135° and a distance of 0″.3 from the source of the normal Me-type spectrum. This result is of especial interest in connection with van Maanen's peculiar value for the parallax of this star.

An examination of the measurements of the sharp bright lines which appear as the star decreases in brightness makes it clear that essentially all of them may be identified with low-temperature lines known in laboratory sources, nearly all of the prominent iron lines of this type being represented. The change from absorption to emission in the case of these lines as the star grows fainter appears to be accompanied by a reduction of temperature in the star's atmosphere which increases their relative prominence.

Spectral Classification of the Faint Stars in the Selected Areas.

This work has been continued by Humason with the slitless spectrograph on the 60-inch reflector. The average exposure time for each photograph is four hours. Seventeen areas have been observed during the year, making a total of 24 which have now been completed. The average number of stars classified in each area is 16, most of them with magnitudes between 11 and 12 on the photographic scale.

Miscellaneous Investigations.

A study has been made by Merrill of the general physical characteristics of the spectra of 22 S-type stars. The most important result is the identification of the strong bands in the red portion of the spectrum with those due to zirconium oxide.

Spectrograms of R Coronæ were obtained by Joy and Humason near the minimum of light, which occurred in May. A number of bright enhanced lines, many of them due to titanium, appeared at this phase, but soon disappeared as the star's brightness began to increase. The general type of the spectrum did not show any very marked change.

Observations of the two eclipsing variables RS Canum Venaticorum and RT Lacertæ at primary minimum of light show nearly the same spectral type, K0 for both stars, but indicate that the former is a dwarf and the latter a giant in its spectral characteristics.

Several stars of type B with bright lines in their spectra have been studied by Merrill and Humason. Some of these show remarkable changes within a very few days. Humason has also obtained slitless spectrograms of several faint variable stars and a number of the older novæ.

INTERFEROMETER MEASUREMENTS OF STELLAR DIAMETERS.

Nearly all of the stars previously observed have been remeasured by Pease with the 20-foot interferometer on the 100-inch telescope. The values for the brighter stars remain practically unchanged, except in the case of α Orionis, for which readings on two successive nights showed a separation of 14 feet between the two primary mirrors before the fringes disappeared. The previous readings were 10 feet in 1920 and 8.5 feet in 1921. The star will be observed carefully in an attempt to correlate these differences with variations in light and radial velocity.

Several stars of visual magnitude about 2.5 have been under observation and the slight differences found in the visibility-curves indicate smaller angular diameters for the stars of earlier spectral type.

It is evident that any considerable advance in the measurement of stellar diameters must await the completion of the 50-foot interferometer telescope now under construction in the instrument shop.

RADIOMETRIC OBSERVATIONS OF STARS.

The measurement of stellar radiation with the vacuum thermo-couple has been continued by Pettit and Nicholson as a regular part of the observing program of the 100-inch reflector. During the year, 352 sets of observations have been made and recorded with the photographic registering device, each set consisting of 7 deflections on total radiation and 7 deflections through the 1-cm. water-cell. The observations on each night include three or more measurements on two stars, one early and the other late in the night, over an interval during which the air-mass for each changes about threefold. These are used for the determination of the absorption coefficients of the atmosphere for the night.

Considerable attention has been given to long-period variable stars, 22 of which have been observed. Since March 1922, R Leonis has been observed on 14 nights, R Aquilæ on 11, and o Ceti on 12. The faintest star of this class so far studied is χ Cygni, which was of the twelfth magnitude on May 17, 1923. Its total radiation on that date was equal to that of Regulus, a star of type B8 and magnitude 1.3. The variable, accordingly, was radiating 19,000 times as much energy as an A0 star of the same magnitude. On September 24, 1922, the star had a magnitude of 4.3 and gave a deflection but slightly greater than that from Altair, or only about 230 times the radiation of an A0 star of equal magnitude. For a change in light of 1,320 times, the total radiation changed but 1.7 times, thus indicating the rapid shift of energy into the visible spectrum as the variables of this class approach their maxima of light.

Observations of the Cepheid variables δ Cephei and η Aquilæ show an absorption by the water-cell of about 0.4 magnitude at maximum of light and 0.6 at minimum. These values correspond to those given by an F0 star at maximum and an early G star at minimum, results which are in close agreement with the spectroscopic observations.

Nova Aquilæ of 1918 was observed on September 25, 1922. The water-cell absorption amounted to 0.2 magnitude, which corresponds to that of a star of an early B-type.

A small spectrograph has been constructed for obtaining stellar spectral energy curves with the thermo-couple. A preliminary trial of the instrument at the Newtonian focus of the 100-inch reflector has given satisfactory photographic curves for Arcturus and Antares. An eyepiece containing a cell filled with a solution of neodymium chloride is used for observations of the spectrum as it traverses the thermo-couple junction, thus making it possible to determine reference points in the visible spectrum.

LABORATORY INVESTIGATIONS.

THE ULTRA-VIOLET SPECTRUM OF TITANIUM.

King has made a study of the titanium spectrum in the ultra-violet with the electric furnace, beginning at λ2600 and extending to λ3900, the limit of a former investigation. The incompleteness of existing wave-length tables, together with the requirements of a search for related lines, has necessitated an especially thorough examination of the effect of different light-sources and the measurement of many new lines. The furnace temperatures employed ranged from 2000° to 2700° C. for both emission and absorption spectra. According to the usual method, the intensities at three furnace temperatures and in the arc were employed as a basis for the temperature classification. About 780 lines have been classified in this way, 321 of which either have been measured for the first time or have had their wave-lengths materially improved by the more favorable character of the furnace lines. The spectrum is especially rich in lines which are much more prominent in the furnace than in the arc, while other lines which are very diffuse in the arc are sharp in the vacuum furnace. Experience with other elements indicates that lines relatively strong in the furnace arise from the simpler vibrations and should be the first material to be used in a search for regularities in the spectrum.

The method of mixing in the furnace the element under examination with one having a lower ionization potential has been used with titanium, and the quenching of enhanced lines by this means has been observed, as in the case of the other elements which have been tested. In accordance with Saha's theory, this effect, in the absence of known series relationships, offers proof that these lines arise from the ionized atom. While the furnace gives only the stronger enhanced lines, it is found to emit these more readily in the region of shorter wave-lengths. Photographs of the spark spectrum made on a large scale show a variety among the lines of the ionized atom, as regards ease of production, structure, and reversal phenomena similar to that found among the lines of the neutral atom.

The method of treating furnace, arc, and spark spectrograms in the ultra-violet has been extended to λ5000, to include the region most used in stellar spectra. Aside from the measurement of some furnace lines not previously listed, this has provided a check upon the earlier classification.

TITANIUM-OXIDE BANDS IN THE ELECTRIC FURNACE.

The green, yellow, and red bands of titanium oxide, prominent in the spectra of M-type stars and of sun-spots, have been examined by King at various furnace temperatures, both in emission and absorption. The bands appear at a lower temperature than the lines in this region, and the relative strength of lines and bands can be controlled closely by the supply of oxygen. Titanium oxide, when placed in the furnace, seems to be dissociated rapidly, and is much less effective in producing the bands than a stream of oxygen led through the tube over metallic titanium. In connection with these observations, the bands have been photographed on a large scale for a study of their structure.

GENERAL ELECTRIC-FURNACE INVESTIGATIONS.

The arc lines of silicon, λ4103, and the enhanced pair λ4128 and λ4131, which are important in certain stellar spectra, have been measured by King on high-dispersion plates of the "tube-arc" spectrum. The spark triplet λλ4553–75, belonging to the second stage of ionization, was found to be just beyond the reach of this excitation. Measurements of λ4103 on photographs of the arc in air agree closely with the tube-arc value.

Lines which are difficult to measure with accuracy in the arc and spark, on account of diffuseness, dissymmetry, or tendency to reverse, may be photographed as sharp lines in the vacuum furnace by a proper selection of temperature. The addition of iron to the furnace supplies standard lines. Lines of the sharp and diffuse series of magnesium and λ4227 of calcium have been photographed in this way for the use of St. John in a comparison of solar and laboratory wave-lengths.

King has also made a number of furnace and arc spectrograms of calcium, strontium, and barium in the ultra-violet to provide the material for studies of the series relationships in these spectra.

REGULARITIES AND GROUPS IN LABORATORY SPECTRA.

Dr. Russell has devoted considerable attention to the study of groups of lines in spectra obtained from laboratory sources. Several groups in the spectra of strontium and barium have been identified as "combinations" between recognized spectroscopic terms and new terms, and further evidence has been obtained in support of Bohr's view that the corresponding quantum changes involve simultaneous alterations in the orbits of two electrons.

An investigation of the spectrum of titanium, undertaken with the aid of data furnished by King and Babcock, has revealed striking regularities. More than 250 lines have so far been classified, including all the strongest and a large majority of those which appear at low temperatures. The spectroscopic terms so far discovered are triple or five fold (perhaps analogous to the single and triple terms in calcium), and their combinations give rise to "multiplets," or groups of from 6 to 13 lines. The strongest members of these groups account for the conspicuous sets of 3, or occasionally 5, lines which are so prominent a feature of the titanium spectrum. Since many of these lines, originating from different levels, are in the region included by ordinary stellar spectrograms, they are likely to be of considerable astrophysical importance.

No series of the ordinary type have yet been found in titanium, and the ionization potential can not be determined. The principal resonance potential appears, however, to be 2.38 volts, corresponding to the strong lines λλ5173, 5192, 5210, with a weaker one, corresponding probably to an "outer system" combination, at 2.27 volts (λλ5426, 5460, etc.). There may be one at 0.80 volt, corresponding to a transition between the lowest spectroscopic term and the next, but observations in infra-red are required to decide this.

Dr. and Mrs. Kiess have discovered 10 of these multiplets (Proc. Wash. Acad. Sci., 13, 220, July 1923), but the arrangement of the lines differs in several cases. The present investigation was well under way before it was known that they were at work on the problem.

ELECTRICALLY EXPLODED WIRES.

The work with electrically exploded wires has been continued by Anderson, with the assistance of Sinclair Smith. An important improvement is the use of a rotating octagonal mirror in place of the single plane mirror, with the result that every spark or explosion projected on the slit is recorded on the photographic plate. Heretofore only about one explosion out of three was recorded. A new and accurately made slit has also been provided.

The explosion of tungsten, aluminum, and lead wires in a very high vacuum was undertaken by Smith, and after many trials was accomplished successfully. In order to be sure that the wires exploded properly, each flash was recorded on a photographic plate. The photographs show plainly what occurs, especially in the case of tungsten wire. If the vacuum is insufficient, the wire, when it becomes hot enough to melt, breaks into a number of short segments, some of which may be melted into little globules. These are projected against the sides of the glass bulb, where they are reflected, a small globule or short segment of the wire sometimes traversing the space within the bulb several times before it cools to such an extent that its light no longer affects the photographic plate. Since the wire may break into dozens or even hundreds of small pieces, the photograph occasionally is very striking. If the vacuum is sufficiently good, however, the explosion is normal, and the photograph shows only the uniform cloud of incandescent metallic vapor.

In every case of a perfect explosion no trace of gas was found, the bulb remaining non-conducting after the explosion, with 26,000 volts applied. It is therefore certain that with the apparatus employed no decomposition of the heavy metallic atoms into helium or other gases takes place. On the average, about a week was required to prepare the bulb, bake it out, and secure the necessary vacuum for these experiments.

Interesting results have been obtained with the vacuum-spark spectra of metals. The discharge of the large condenser was passed between metallic electrodes separated about 2 mm. in a good vacuum. The maximum value of the momentary current flowing through the gap was about 10,000 amperes, and in the case of most of the metals tried the spark was extremely brilliant. The spectrum which was photographed with a concave-grating spectrograph in both first and second orders is very rich in lines. The lines, due to the residual gas, are weak or entirely absent, depending upon the metals which are used as terminals. With aluminum a few oxygen lines show, while with zinc or cadmium no certain trace either of oxygen or nitrogen has been found. Calcium, the first metal investigated, gives a spectrum consisting of about 900 lines in the ordinary photographic region. Of these, approximately 75 are known lines of calcium or of impurities, mainly magnesium and strontium. The remaining 800 or more lines appear to be chiefly lines of calcium in a higher state of ionization than that occurring in the arc or ordinary spark. Many of the lines are very strong.

A large condenser is now under construction for work on wire explosions and the vacuum spark and, in July, the 218 glass plates were received from the manufacturers. The proper design of this condenser, to insure permanence and efficiency in operation, is a problem which demands a considerable amount of experimental work. When completed, the condenser will have nearly the same capacity as the one now in use, and if, as we hope, it will withstand 5 times the voltage used at present, it will furnish approximately 25 times the energy now available.

Anderson is continuing the study of the vacuum-spark spectra of metals. Spectrograms have been secured for the following elements: aluminum, carbon, calcium, cadmium, copper, iron, magnesium, lead, and zinc. Spectra of the remaining available metals will be photographed as soon as possible.

STUDIES OF THE ZEEMAN EFFECT.

Extensive measurements of the Zeeman effect for iron, chromium, and vanadium, which were begun some years ago by Babcock, primarily for comparison with observations on sun-spots, but which are for the most part still unpublished, have assumed new importance since the recent visits of Professor Sommerfeld and Professor Russell. The value of this material in the difficult problem of finding series relationships in complicated spectra is proving so great as to require its rapid extension to certain other elements. An examination of the data on iron, chromium, and vanadium from this new point of view has been completed, with numerous valuable results. Measurements are now in progress on titanium. The data have already been placed at the disposal of Sommerfeld and Russell, under whose direction much is being accomplished in reducing these spectra to rational systems based on the quantum theory.

THE RATIO e/m.

A considerable body of observational data on the Zeeman effect, which has been collected during previous years, has recently been discussed by Babcock for a new determination of this important ratio. The spectroscopic material is of greater variety and extent than any hitherto used in this way, and the absolute magnetic measurements are of ample accuracy for the purpose. An analysis of the influence of the various factors involved in this method of determining e/m shows that further increase of accuracy will require higher spectroscopic resolving power and magnetic fields of greater intensity.

Forty-nine separate values of the ratio have been derived, which yield a mean result of $e/m = 1.761 \times 10^7$ with an estimated uncertainty of 2 or 3 parts in 1,800. Dr. Birge, using this value of e/m, has calculated the value of Planck's constant h, and finds a result in excellent agreement with the most probable value of h based on a variety of methods.

FAINT ARC-LINES OF IRON.

Lines easily measurable in the solar spectrum are often so faint in ordinary laboratory sources as to require special conditions for their observation. About 150 such iron arc-lines have been specially studied by Babcock with the 15-foot concave grating. Their wave-lengths have been measured on some photographs with long exposures taken by Smith for another purpose, and the results furnish data for comparison with their positions in the solar spectrum. For many of the lines no other modern measurements are available.

VACUUM THERMO-COUPLES.

Pettit and Nicholson have continued their laboratory studies of thermo-couples and methods for improving their sensitiveness. By reducing the mass of the thermo-couple to 0.01 mg., a gain of one magnitude over previous results has been made in stellar observations. The two junctions are connected in such a way that they may be used either singly or together as a compensated thermo-couple. Cells have been constructed for various purposes with windows of microscope cover-glass, quartz, fluorite, and rock salt.

In preparation for the reduction of the stellar observations, several investigations have been undertaken to determine the constants of the apparatus employed. For this purpose a rock-salt spectrograph was constructed with a 10-junction vacuum thermopile as the sensitive element. The apparatus was connected to the registering device of the microphotometer and energy curves were obtained showing the transmission of windows made of different materials. The microscope cover-glass used for stellar observations up to March 17 of the present year was found to transmit most of the radiation to 5.5 μ with some transmission to 7 μ. The transmission of crystals of various salts was also studied, with a view to finding a substitute for the water-cell. A plate of potassium alum 1.7 mm. thick, which may be obtained in large crystals and shows a satisfactory degree of permanency when polished, is found to transmit throughout the visual region and as far as 1.5 μ without absorption bands. At this point the transmission falls off sharply. This material, therefore, should make a desirable substitute for the water-cell.

The results of other investigations show: first, that there seem to be no grounds for suspecting a variation in the transmission of the water-cell due to temperature or prolonged use; second, that the reflecting power of the silver films in the telescope appears to be constant for angles ranging from 45° to perpendicular incidence; third, that the variation in radiation of the 100-watt nitrogen-filled lamp used at the telescope as a check on the sensitiveness of the apparatus is directly proportional to the power used between the limits of 40 and 110 watts; fourth, that the source of drift appears to be inherent in the thermo-couples, some being entirely free from it and others showing it to a marked extent.

The D'Arsonval galvanometer as at present used for stellar observations is placed at a distance of 7 meters from the registering apparatus, this limit being set by the size of the room available. By the aid of multiple reflections between the galvanometer mirror and a fixed mirror the deflection may be increased in arithmetical progression with the number of reflections. As many as 5 reflections were used on one occasion, which gave as the sensitivity of the galvanometer 5×10^{-11} ampere per millimeter. Observations of the deflections given by the thermo-couple with changes in the amount of radiation received show the scale to be uniform over a wide range.

THE REGISTERING MICROPHOTOMETER.

Several improvements in this instrument have been made by Pettit. Among these are a motion which quickly returns the plate-carriage to the starting-point, and a Julius suspension for the galvanometer which eliminates small irregularities in the photographic curves due to earth tremors. A study of the resolving power of the instrument shows that after the width of the first slit is reduced to 0.01 mm. no gain can be made by further narrowing, on account of the effect of diffraction. An increase may be obtained by reducing the width of the slit in front of the thermopile, but with the result that some scattered light from the illuminated film falls upon the junctions. Investigations have been made of the variation of the deflections with slit-width and slit-length and with changes in the voltage of the battery which supplies current to the lamp.

The microphotometer has been used by St. John and Miss Ware in studies of line-structure and wave-lengths in the solar spectrum, by Hubble in investigations on nebulæ, and by Pettit in mapping special regions of the solar spectrum, with a view to the determination of the intensities of the spectral lines.

OTHER INVESTIGATIONS.

THE GREEN AURORAL LINE.

The preliminary observations of this interesting line by Babcock have been considerably extended during the past year, and the interference method has been applied to a precise measurement of its wave-length and to a study of its width and brightness. The wave-length is found to be 5577.350 I. A. with an uncertainty estimated to be not greater than 1 part in 1,000,000. The width of the line is shown to be less than 0.035 A, a value which may be even further reduced by subsequent observations with a large interferometer recently constructed. Finally, the order of magnitude of the surface brightness of the diffuse green auroral light in the background of the sky has been found to be 10^{-8} times that of the green radiation from a mercury lamp.

For the purpose of correlating the brightness of the persistent aurora with the occurrence of certain solar and terrestrial phenomena, a small etalon has been constructed and provided with a camera and automatic shutter. This etalon is made of very thin plane-parallel glass, with cover-glasses cemented over films of gold, and so has constant absorptive power. Since it remains permanently in adjustment it is adapted to the use of observers unfamiliar with the technique of interferometry.

A consideration of the probable temperature of the upper levels of the earth's atmosphere in connection with the limiting value of the line-width indicates for the origin of the green line a gas whose atomic weight is at least 4.

THE VELOCITY OF LIGHT.

Two alternative plans have been under consideration by Dr. Michelson in connection with this investigation. In the first, which is a combination of the methods of Fizeau and Foucault, the image of the slit is focused on a concave mirror from which the light returns to the revolving octagonal mirror, thence to the concave reflector of 30-foot focal length, and from this to the distant station on the San Antonio ridge. In front of the first concave mirror is placed a grid which corresponds to the teeth of the Fizeau wheel. The chief difficulty encountered in this arrangement is the scattered light from the mirror and grid. This may be overcome to a large extent by using the sputter process on both mirror and grid (the bars in the latter being inclined to avoid direct reflection). It is estimated that this form of apparatus will furnish results considerably more accurate than those now in use if the second arrangement about to be described does not furnish sufficient light. The accuracy will depend upon the spacing of the grid, increasing in proportion to the total number of intervals. If it is possible to make this as large as 500, the order of accuracy may be estimated at 1 in 25,000. In view of the faintness of the return image, however, it is doubtful if the light scattered from a grid of this character would permit of sufficient accuracy in the estimate of brightness.

The second method, which is a modification of that of Foucault, seems on the whole to be more promising and is certainly much simpler. In this arrangement the return light is very much fainter than in the method already described, but it is possible to eliminate the scattered light entirely. Moreover, the determination by this method depends upon observations of the position of the return image and not upon estimates of brightness. The expression for the intensity of the return image is

$$I = bd^2/Dr^2$$

in which b is the width of the face of the octagonal mirror, d the diameter of the concave mirror, r the distance of the image from the octagonal mirror, and D the distance between the stations. The accuracy of the measurement is directly proportional to r, so that a compromise must be made because of rapid diminution of brightness with increase of r. A preliminary trial under rather unfavorable conditions due to haze, unsteadiness of the air, insufficient adjustment of the apparatus at the distant station, and low intensity of the source of light, indicated that the return image would be sufficiently bright for measurement under favorable conditions with a value $r = 250$ mm. This would insure an order of accuracy of about 1 part in 50,000. If it is considered practicable to place two, or better three, concave reflectors at the distant station, the value of r could be nearly doubled, with a corresponding gain in accuracy.

More reliable data would have been obtained with the present arrangement of apparatus, but that an exceptional amount of haze and smoke in the air between the two stations, due in part to forest fires, has made observations very difficult. Since the chances for immediate improvement did not appear promising, Dr. Michelson returned to Chicago about August 15 with the intention of resuming observations at Mount Wilson at a somewhat earlier date next year.

Through the cooperation of the Coast and Geodetic Survey, the measurements have been completed for a very accurate determination of the distance between the two stations used by Dr. Michelson for this investigation. The work has been under the immediate direction of Mr. C. L. Garner, and the reduction of the observations is being completed in Washington.

EFFECT OF THE EARTH'S ROTATION ON THE VELOCITY OF LIGHT.

Reference was made in the last annual report to the experiment devised by Dr. Michelson to detect possible displacements of interference fringes due to the rotation of the earth. Dr. Michelson has decided to use a pipeline exhausted of air for this work and will undertake the investigation in the vicinity of Chicago, the necessary funds having been provided for the purpose.

THE TORSION SEISMOMETER.

As a member of the Advisory Committee on Seismology, Anderson has assisted Dr. H. O. Wood in the development of seismometric instruments for registering earthquakes of a local nature. A new type of instrument called the torsion seismometer has been devised. Continuous records have been made with one of these instruments since late in January 1923, with results which are satisfactory in every way. A full account of the instrument and its performance will be found in the annual report of the Advisory Committee on Seismology.

PREPARATIONS FOR THE SOLAR ECLIPSE OF SEPTEMBER 10, 1923.

Reference has already been made to the general plans for observing this eclipse which have occupied for several months the attention of the members of the staff as well as of the departments of design and instrument and optical construction. These plans involve: first, direct photography of the corona and the field of stars near the sun, together with photometric, radiometric, and spectroscopic observations of the corona at a station near the center of the path of the shadow at Point Loma, California; second, spectroscopic observations of the flash spectrum with slitless concave-grating spectrographs of various focal lengths at a station near the edge of the shadow at Lakeside, California; third, observations at Mount Wilson with the Snow and tower telescopes of the spectrum of the cusp and of the narrow uneclipsed crescent. Apart from the use of the single large equatorial mounting for all of the instruments at the central station, the principal new features of this program will be the attempt to apply the interferometer to a study of the coronal spectrum, and the vacuum thermo-couple to a study of its radiation. The great variety of spectroscopic apparatus and the use of the powerful telescopes on Mount Wilson on the thin crescent are the other main characteristics of the plans which have been developed.

CONSTRUCTION DIVISION.

DRAFTING AND DESIGN.

The outstanding piece of work in this department, which has been carried on by Pease, Nichols, and H. S. Kinney, has been the detailed design of the mounting and central section of the 50-foot interferometer and its adaptation for use at the solar eclipse. The design of the numerous instruments for the eclipse and of additional equipment for the laboratory and for Mount Wilson has all been planned and worked out in detail with the general assistance of the members of the staff. Among the drawings made for these pieces of apparatus are the following:

Fifty-foot interferometer: Pedestal, polar axis, structural-steel beam, driving-clock and worm, fast and slow motions, and general assembly.
Eclipse expedition: Assembly of instruments, coronal and stellar cameras, interferometers, radiometric apparatus, objective grating, and prismatic spectrographs.
For the 100-inch reflector: Thermo-couple spectrograph, ultra-violet spectrograph mounting, 10-inch lens mounting, brake on right-ascension slow-motion motor, mounting for mirrors of 20-foot interferometer.
Miscellaneous: Spectroscope for testing gratings, 8-inch by 18-inch comparator, adapter for stereocomparator, modification of slow motions on mirrors of Snow telescope.

Several drawings have been made in connection with the design of the astronomical apparatus for the new building of the National Academy of Sciences at Washington. Drawings and sketches for the publications of the Observatory have been continued, as in previous years.

OPTICAL SHOP.

In the optical shop, W. L. Kinney has made several large mirrors and prisms, while Dalton has devoted much of his time to figuring speculum plates for use in the ruling-machine. Among other pieces of optical apparatus are the following: A 27-inch paraboloidal mirror for use in radiometric work; a 22-inch paraboloidal mirror and a 4-inch convex to be used as a Cassegrain combination by Dr. Abbot in spectro-bolometric work; a 60° prism with faces 8 inches by 8 inches; 30 speculum plates for diffraction gratings, and a large number of small prisms, lenses, and plane-parallel plates of quartz, rock salt, alum, and other substances, mainly for use in the laboratory.

Work in glass-blowing and the manufacture of glass and quartz apparatus has been carried on by Pompeo, who has continued to devote a part of his time to this purpose.

INSTRUMENT SHOP.

The construction of the mounting of the 50-foot interferometer telescope and of the apparatus designed for use at the solar eclipse has made heavy demands upon the instrument shop, especially during the summer months. That this work should have been accomplished successfully and in ample season for necessary tests and adjustments of the instruments is due to the efforts of all those associated with it, and especially to the skill and active interest of the members of the force of the instrument shop, who, under the immediate direction of Ayers, have carried it to completion.

Other work of the year has included the following construction: Measuring machine for 4 by 10 inch plates; 3-prism stellar spectrograph; slow motions for Snow cœlostat; driving-clock for small cœlostat; spectrograph for testing gratings; new mirror mountings for 20-foot interferometer; thermo-couple spectrograph; large coudé spectrograph. Repairs on our existing instruments have been continued regularly and work has been done on apparatus for Dr. Michelson's investigations and Dr. Wood's seismological instruments.

A marked improvement has been made in the driving of the 100-inch telescope by planing the large steel cylinder which forms the southern element of the mercury flotation system. Because of great difficulty in obtaining mercury at the time the telescope was erected, the clearance between the float and the trough in which it rotates was made as small as possible. As a consequence, owing to expansion or contraction of the mounting, the float has occasionally touched the sides of the trough and introduced a periodic error into the motion of the telescope.

A simple and permanent solution of this difficulty has been found in a reduction in size of the float. A special planing mechanism was designed and attached to the side of the mercury trough, the float being rotated under the cutting tool by the regular driving mechanism of the telescope. The work was done by Kimple and Sam Jones, of the instrument shop, and involved planing an area of about 125 square feet to an average depth of one thirty-second of an inch. The result has been the complete elimination of the error in driving.

BUILDINGS, GENERAL CONSTRUCTION, AND TRANSPORTATION.

The principal new work on Mount Wilson has been the erection of a house to provide dining quarters for men engaged in construction work and living quarters for a cook. The house previously used for this purpose will be remodeled to furnish adequate living quarters for the men. In this way the difficulties arising from the use of temporary shelters during inclement weather will be avoided.

George D. Jones, superintendent of construction, has also carried on much other general work, including retaining-walls and improvements on the mountain road, grading around the new reservoir, painting of the large domes and 150-foot tower telescope, and building repairs in Pasadena. In August he went to Point Loma to superintend the transportation and erection of the apparatus for use at the eclipse.

Merritt Dowd, engineer on Mount Wilson, and Sidney Jones, assistant engineer, have laid the electrical cables in 700 feet of new conduit line and have made many additions to the electrical equipment of the instruments. They have had complete charge of the maintenance of the power, water, and light services upon which the observational work on Mount Wilson depends.

Through the aid of a special appropriation, the Observatory was able to purchase during the winter a Holt tractor of the caterpillar type. This has already proved of very great value for grading on the mountain top, transportation on steep grades, and especially for opening the mountain road after heavy snowstorms when the ordinary motor truck can not be used.

INVESTIGATIONS IN PROGRESS.

It is naturally difficult in any statement of the scientific activities of the Observatory to make a distinction between the results already accomplished in many fields of investigation and those which depend upon a continuation of the work in progress. A summary of the principal researches upon which the members of the staff are immediately engaged is of value, however, both for the direct information which it conveys regarding the problems under consideration and for the insight afforded into the interrelationship of different investigations and the manner in which one may develop from another.

SOLAR RESEARCH.

The regular work in direct photography and with the spectroheliograph is being continued as usual, and especial attention is being given to active areas on the sun's surface. Apart from the value of these photographs as records of the solar activity, exceptional interest attaches to them in view of Dr. Abbot's investigations of the correlation between the solar constant and sun-spots and solar disturbances.

The study of the polarities of sun-spots is especially interesting because of the approach of the new cycle. A continuous record is being maintained of all visible spots, and the search for new invisible spots by means of their magnetic fields is a regular feature of the work. Closely allied with this is Hale's extensive study of the nature of the magnetic field in sun-spots as revealed in the spot spectrum and of the hypothesis of the nature of sun-spots to which it gives rise. During the present spot minimum this work consists mainly in the measurement and discussion of the photographs obtained several years ago, but with increasing spot activity the accumulation of new material will be resumed.

Radiometric observations of the sun's surface are being continued, and similar observations on sun-spots will form an important part of the solar program as the number of spots increases.

In the field of solar spectroscopy numerous investigations are in progress. Among these, reference may be made to the new series of photographs for a study of the sun's general magnetic field, the continuation of the work on the solar rotation, determinations of the wave-lengths of lines in the solar spectrum on the international system, and an extensive study of the displacements of lines between the center and limb of the sun. The last two of these investigations bear directly upon the question of the gravitational shift of the spectral lines, which forms so essential a part of the generalized theory of relativity.

NEBULAR AND STELLAR RESEARCH.

Direct photography of nebulæ is being continued, both for purposes of classification and to aid in studies of luminosity, and photographs of the larger spirals are being accumulated to serve as a basis for future measurements of internal motion in these objects. The important question of the source of luminosity in nebulæ will be further studied by spectroscopic observations and measurements of color indices.

Trigonometric measurements of parallax are being made for a selected list of objects, including stars of large and small proper motion, planetary nebulæ, and distant companions of stars of known motion.

The principal photometric work in progress on the stars of the Selected Areas is the continuation by the method of exposure ratios of the determination of the colors of the stars in the 30° zone. The photographs of shorter exposure time are being supplemented by exposures of 64 minutes, which will extend the determinations to stars of the seventeenth photovisual magnitude. A detailed account of the methods and the results of many miscellaneous observations are in preparation for publication. The results for a large number of stars of selected spectral types and absolute magnitudes will also be published and should afford improved values of the numerical relationships between color index, absolute magnitude, and spectral type.

In the field of stellar spectroscopy, work is being continued on an extensive list of stars which includes many stars of large proper motion, visual binaries, variables of the cluster type and the fainter Cepheids, the brighter stars in the Selected Areas, spectroscopic binaries, and most of the stars of Boss's Catalogue. For all of these, determinations both of radial velocity and absolute magnitude are in progress. The revision and improvement of the present methods for the determination of absolute magnitude through the use of additional spectral criteria and results obtained from trigonometric parallaxes and peculiar and parallactic motions forms an important feature of this work.

Additional investigations in stellar spectroscopy include detailed physical studies of types Me and S, helium stars with bright lines, stars of the α Cygni type, and former novæ. The brighter stars in globular clusters are being observed for radial velocity and spectral type, and the classification of the spectra of stars in the Selected Areas to the twelfth magnitude is a regular part of the observational program.

The application of the results of determinations of radial velocity and absolute magnitude to studies of the distribution of the motions of stars in space has led to important conclusions and is one of the principal objects of the work in progress. Of especial interest in this connection is the investigation of the space-velocities of the stars of types Me and R, both of which are characterized by an exceptionally large dispersion in motion.

Radiometric observations of stars and planets with a highly sensitive thermo-couple are being continued regularly, and are yielding most valuable information regarding the nature of the radiation and the physical conditions in these bodies.

LABORATORY RESEARCH.

The use of the electric furnace for the production of spectra at relatively low temperatures under conditions easily controlled, and the powerful methods of wire explosions and vacuum sparks for very high temperatures, form a most valuable means of attack upon problems relating to ionization and series relationships in complex spectra. The classification of lines according to their behavior in the electric furnace over a long range of spectrum is providing a basis for the selection of groups of lines of similar constitution separated by recurring intervals in their vibration-frequencies. Such groups form the material for the determination of the series of lines emitted by electrons at different energy levels.

Of equal importance for investigations of this character is the detailed study of the Zeeman effect and the measurement of the separations of the components of the spectral lines in a magnetic field. A strong incentive to further work is provided by the remarkably successful application of the quantum theory to the interpretation of complicated spectra.

The use of the method of the vacuum spark has widened very greatly the field of study of the spectra of the elements. The result found in the case of calcium, a spectrum rich in lines, very few of which can be identified with known lines of this element, leads to the conclusion that a state of ionization is attained which is decidedly beyond that reached in ordinary sources. Numerous other elements are now under investigation in the laboratory by this method, and the results are certain to prove of physical interest and very possibly to have astrophysical applications.

The determination of the wave-lengths of spectral lines in the electric furnace at ordinary pressures and in vacuo, interferometer observations of wave-length, radiometric measurements of the energy of various light-sources, and studies of the width and intensities of lines with the registering microphotometer form a portion of the other investigations in progress in the physical laboratory.

NUTRITION LABORATORY.[1]

FRANCIS G. BENEDICT, DIRECTOR.

With a pre-war budget the problem of maintaining the staff and the scientific output of the Nutrition Laboratory at its normal level is becoming more difficult. Attention was called in the last report to the importance of cooperative investigations in enlarging the scientific activity of the Nutrition Laboratory. Another factor which has been but little used since 1913 is again to assume a prominent rôle, that is, periodic visits by staff members to the large research laboratories of America and Europe. Through the printed page, either of monographs or of journal articles, the scientific public is advised of the researches of the Nutrition Laboratory, yet in many instances only personal conferences can give a clear idea of many details.

Prior to 1914, special efforts were made to keep the Laboratory in close contact with European as well as American laboratories and clinics occupied with researches on the nutrition of man and animals. It was thus possible to carry to other scientific laboratories the latest and many times unpublished reports of the researches of this Laboratory and to interchange ideas and hold conferences as to mooted points of research or plans for new work, including at times cooperative efforts. In 1920 our former associate, Dr. W. R. Miles, combined a tour of European laboratories with attendance at the Physiological Congress in Paris, and in 1923 the Director felt justified in a personal resumption of travel. Accordingly, in March 1923, an extended tour was undertaken in order to carry to European laboratories information as to the latest activities of the Nutrition Laboratory, to see the progress of rehabilitation of scientific institutions, to study institutions not previously visited, to give lectures, and to be present at the eleventh International Physiological Congress at Edinburgh, which was attended by representatives from many nations and presided over by Sir Edward Sharpey Shafer. Opportunity was had in this tour to discuss personally with many specialists of Europe problems of international importance, such as those of diet and energy needs on the one hand, and on the other the innumerable abstract problems in physiology of fundamental importance in the planning and conduct of research in metabolism.

In foreign laboratories research has been prosecuted with very great difficulty; but being relatively little disturbed in its scientific activity by the war, the Nutrition Laboratory has in progress or completed a number of major researches as yet unpublished. Lectures embodying the most recent work of the Nutrition Laboratory were given in Paris, Berne, Heidelberg, Halle, and Hamburg, while a communication describing certain new technique was given at the congress in Edinburgh. Numerous conferences were held with physiologists and physicians, with discussions of the latest findings in the Nutrition Laboratory work.

Owing to the food crises due to the war, the use of metabolism measurements in connection with the surgical handling of disease, and the wave of public interest in food problems, receptive audiences were found everywhere. It was a real privilege to be able to carry to the Old World scientific results that were of such interest as to lead one to hope that the great debt of the Nutrition Laboratory to European research institutions was in a measure being repaid. The presentation to scientific and academic circles of information regarding the work of the Carnegie Institution of Washington in general was most profitable.

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[1] Situated in Boston, Massachusetts.

During the absence of the Director on foreign tour, the Laboratory was successfully directed by Dr. Thorne M. Carpenter, who was appointed by President Merriam as Acting Director.

COOPERATING AND VISITING INVESTIGATORS.

Dr. Elliott P. Joslin and his assistants have been occupied in reading and revising the proof of the third diabetic monograph, which has just been issued.

Professor E. G. Ritzman, of the Department of Animal Nutrition of the University of New Hampshire, has, in accordance with a liberal arrangement made by President R. D. Hetzel and Director John C. Kendall, devoted the greater part of his time to the conduct of metabolism studies with large domestic animals. A respiration chamber has been employed for these studies in a separate building provided by the authorities of the University, thus in effect establishing an institute of animal nutrition.

Miss Grace MacLeod, of the Department of Nutrition, Teachers College, Columbia University, New York, with the hearty support of Professors Henry C. Sherman and Mary Swartz Rose, has continued the investigation of the metabolism of the white rat.

Many foreign investigators have visited the Nutrition Laboratory, among them a commission from the University of Strasburg, which included the dean of the Faculty of Medicine, Professor Georges Weiss, and Professors Maurice Nicloux and Leon Blum. We were visited also by Professor and Mrs. August Krogh, of Copenhagen, and Professors H. J. Hamburger, of Groningen; Leon Asher, of Berne; I. P. Pawlow, of Petrograd; Bela Schick, of Vienna; O. Meyerhof, of Kiel; A. Samoiloff, of Kasan; Drs. G. B. Fleming, of Glasgow; F. G. Banting, of Toronto; Paul Roth, of Battle Creek; and S. Hata, of Tokyo.

Mrs. C. G. Benedict worked for several months as a volunteer associate in the Laboratory and during this time developed a new form of respiration apparatus which has created great interest in medical centers.

INVESTIGATIONS IN PROGRESS.

Standardization of respiratory exchange apparatus.—Continuing his critical examination of methods of studying the respiratory exchange, Dr. Carpenter has tested the accuracy of several types of apparatus for the determination of the respiratory exchange, particularly the oxygen absorption. The apparatus used was a mechanico-chemical testing device which comprised a special lamp, a hand spirometer, and a special burette for alcohol or acetone. A study was made of the Benedict and Collins portable respiration apparatus, the Roth modification, a Benedict apparatus with outside blower, and the Benedict student respiration apparatus. A report of the results is now in press. The possibility of applying the Benedict universal respiration apparatus to the determination of the respiratory quotient in continuous periods has been studied, as well as the gasometer method of determining the respiratory quotient. These tests have all been made by Mr. E. L. Fox and Mr. E. S. Mills.

Composition of the urine of steers.—The studies of the composition of steers' urine collected in connection with the metabolism experiments at the Agricultural Experiment Station, University of New Hampshire, have been continued by Dr. Carpenter. Especial attention has been given to the relationships of three forms of sulphur found in steers' urine, viz, inorganic and ethereal sulphates and neutral sulphur, as affected by changes from fasting to feeding and by various planes of nutrition. The daily urinary nitrogen excretion of two steers for a period of 71 days has been determined and the effect of storage upon the quantity of ammonia has been observed. The analyses were done by Mr. Philip P. Saponaro.

Reduction of potassium permanganate by urine.—Studies of transformations of energy in the animal body require a knowledge of the potential energy of the urine in order to be complete. For a number of years the Nutrition Laboratory has had the problem of finding some simple chemical determination for urine whose results would have a relation to the heat of combustion of urine. During the past year the problem has been attacked by Dr. Carpenter from the standpoint of the reduction of an oxidizing agent, viz, potassium permanganate. An intensive study has been made of conditions essential for consistent results in titrating urine with tenth-normal potassium-permanganate solution, and the relations of this value to specific gravity, total nitrogen, total solids, and organic matter have been found. The details have been carried out by Mr. E. S. Mills.

Temperature of the skin.—By means of the thermo-electric element and special technique, skin temperatures of humans, both clothed and nude, were observed in a large number of experiments. Special attention was given to the rapidity of change in skin temperature when the skin is suddenly exposed to cold. In many experiments temperatures taken deep in the body trunk were recorded simultaneously with the surface temperature.

Influence of environmental temperature upon metabolism.—In view of the increasing importance of basal metabolism measurements in clinical medicine, the exact conditions underlying the determination of basal metabolism need closest inspection. The influence of environmental temperature plays a significant rôle, and this factor has been studied under most diverse conditions of temperature, clothing, and wind-velocity.

The insensible perspiration of humans.—In continuance of previous investigations on the insensible perspiration of humans, observations were made with a delicate balance and the rate of body-loss per hour was compared in many instances with the metabolism measurements. The influence of environmental temperature and clothing was a special feature of the investigation.

Development of a simple apparatus for determining gaseous metabolism.—Mrs. Cornelia Golay Benedict worked for several months in developing a new apparatus of extremely simple type for measuring accurately the oxygen consumption of humans. A description of this apparatus, together with the results of a research made with it, has been published and is subsequently reviewed.

The metabolism of steers as affected by environmental temperature.—With the large respiration chamber at the Agricultural Experiment Station, University of New Hampshire, Professor E. G. Ritzman has cooperated in studying the influence of marked temperature changes in the environment upon the metabolism of large ruminants, specifically steers. The gas-analysis apparatus of Dr. Carpenter and the technical skill of Mrs. L. A. Ritzman have secured measurements of the oxygen consumption—an important factor in our studies. Two full-grown steers which have been the subject of much experimentation were used throughout the series. Opportunity was likewise taken to carry on critical experiments elucidating certain points in some of the earlier researches. By means of a reconstruction of the room in which the respiration chamber is placed, it is now possible to surround the apparatus entirely with outdoor air and hence to work at winter temperatures. Professor Ritzman has been assisted in these investigations by Mrs. L. A. Ritzman, Miss H. M. Hilton, and Mr. A. D. Littlehale.

The gaseous metabolism of the white rat.—In addition to the studies of steers at the University of New Hampshire, similar studies in cooperation with Columbia University have been made with the white rat. This investigation was under the direct supervision of Miss Grace MacLeod, assisted by Miss Margaret G. Barwis.

PUBLICATIONS.

A monograph entitled "Alcohol and human efficiency. Experiments with moderate quantities and dilute solutions of ethyl alcohol on human subjects," by Professor Walter R. Miles, is now in proof form. The following publications have been issued during the year:

(1) The work of the Carnegie Nutrition Laboratory. Francis G. Benedict. Report Seventy-seventh Meeting New England Association Chemistry Teachers, Providence, R. I., May 6, 1922, pp. 10–19.

A popular account of the general scope, technique, and results of experiments, with emphasis upon the special factors of pedagogical significance.

(2) Physical measurements of diabetic patients. H. F. Root and W. R. Miles. Jour. Metabolic Research, vol. 2, pp. 173–197 (1922).

A group of 133 diabetic men and women averaged 20 per cent over weight prior to the onset of the disease, although normal in stature. At the time of examination they were about 10 per cent under weight. The women showed more severe diabetes than the men and had much lower carbohydrate tolerance per kilogram of body-weight, whether expressed as total available glucose or as the carbohydrate in the diet. The glucose tolerance per kilogram of body-weight was more uniform for the different diabetic patients than the carbohydrate tolerance. The carbohydrate tolerance, therefore, appears to be the more definitive expression for tolerance in diabetes. The older diabetics had been more obese, had lost a larger percentage of their maximum weight, and demonstrated the longer durations. Diabetics who had never been obese according to medico-actuarial standards were found to have been 10 per cent over weight when compared with Dreyer's standard. They were distinguished by abnormally narrow chests and probably had been fat for their build. Obesity is closely related to the onset of diabetes mellitus, in fact is almost invariably present, but the intensity of the disease is frequently inversely proportional to the amount of excess fat. The average diabetic patient is not physically fit, if body-weight is used as an index, but his vital capacity may be as large as that of normal individuals, notwithstanding his bodily weakness. Vital capacity measurements in uncomplicated diabetes are not clinically helpful.

(3) The urinary sulfur of fasting steers. Thorne M. Carpenter. Jour. Biol. Chem., vol. 55, Proc. Soc. Biol. Chemists, p. iii (1923).

An abstract of a paper presented at the seventeenth annual meeting of the American Society of Biological Chemists at Toronto, December 1922.

(4) A gas-analysis apparatus for use with chamber respiration apparatus. A demonstration. Thorne M. Carpenter. Jour. Biol. Chem., vol. 55, Proc. Soc. Biol. Chemists, p. xix (1923).

A brief description of a gas-analysis apparatus demonstrated at the tenth annual meeting of the Federation of American Societies for Experimental Biology at Toronto, December 1922.

(5) The basal metabolism of young girls. Francis G. Benedict. Boston Med. and Surg. Jour., vol. 188, pp. 127–138 (1923).

Data on the basal metabolism of two groups (12 each) of Girl Scouts, one 18 and one 14 years of age, are given which supplement data previously reported on the metabolism of young girls (Benedict and Hendry, Boston Med. and Surg. Jour., vol. 184, pp. 217, 257, 282, 297, and 329, 1921). These supplementary findings are in full conformity with the earlier data, and it may be considered as definitely established that young girls from 12 to 18 years of age have on the average a basal heat-production of 1,250 calories per 24 hours and that during the 10 hours ordinarily spent in bed their basal heat-production will be approximately 550 calories. The Girl Scout measurements, together with the data for younger girls, infants, and adult women, make it possible to obtain a reasonably smooth curve indicating the average course of the metabolism of females from birth to old age, on the basis of the 24-hour heat-production per kilogram of body-weight referred to body-weight. It is impossible to secure such a smooth curve on the basis of heat-production per square meter of body-surface. For purposes of predicting the basal metabolism of young girls, a table is given, based upon a smoothed curve, indicating the probable basal heat-production per kilogram of body-weight per 24 hours for each half year from 12 to 18 years. The prediction of the basal metabolism of young girls from this table, however, must be made with the greatest caution, and deductions should be drawn with very great reserve. The Girl Scout values are seemingly much lower than are commonly found with young girls, and although it can not be considered that their metabolism is abnormally low, it should be pointed out that the values were obtained during sleep. Another complicating factor is that while with adults undernutrition depresses metabolism, singularly enough during youth undernutrition apparently increases metabolism.

(6) Nouvelles recherches du "Nutrition Laboratory" de Boston sur le métabolisme de l'homme et des animaux. Francis G. Benedict. Bull. Soc. Sci. d'Hygiène Alimentaire, vol. 11, pp. 343–363 (1923).

An address given in the amphitheater of the Société Scientifique d'Hygiène Alimentaire, Paris, April 14, 1923, describing the new researches (for the most part unpublished) which have been made or are in progress at the Nutrition Laboratory.

(7) A student form of respiration apparatus. Francis G Benedict and Cornelia Golay Benedict. Boston Med. and Surg. Jour., vol. 188, pp. 567–577 (1923).

To aid in introducing to medical students the fundamentals of gaseous-metabolism measurements a simple type of apparatus is described, involving the breathing of a confined volume of oxygen-rich air and measuring exactly the amount of oxygen absorbed by the lungs of the subject. A can two-thirds filled with soda-lime, a bathing-cap for expansion, two rubber valves and housings, with rubber hose and mouthpiece, comprise the respiration system. Dry room air is forced quantitatively (by an automobile grease-gun) into the can as the oxygen is absorbed. From the volume of 6 full strokes of the air-pump, the temperature of the pump, the barometer, and the time in minutes, the actual oxygen consumption is rapidly computed. The apparatus lends itself also to the determination, by students, of the vital capacity.

(8) Ein einfacher Respirationsapparat. Francis G. Benedict and Cornelia Golay Benedict. Skand. Arch. f. Physiol., vol. 44, pp. 87–102 (1923).

A somewhat different treatment for foreign readers of the English description (just cited) of a new respiration apparatus.

(9) A permissible breakfast prior to basal-metabolism measurements. Cornelia Golay Benedict and Francis G. Benedict. Boston Med. and Surg. Jour., vol. 188, pp. 849–851 (1923).

One discomfort commonly experienced by all subjects of basal-metabolism measurements is the feeling of hunger caused by the necessity of abstaining from food completely for at least 12 hours. A light breakfast was therefore planned, to satisfy the appetite but not unduly stimulate metabolism and thus vitiate the basal-metabolism measurements. This breakfast consists of 1 cup (200 c. c.) of caffeine-free coffee, 16 mg. of saccharin, 30 grams of medium cream, and 25 grams of potato chips. Its effect upon the basal metabolism was studied by making basal-metabolism measurements until a well-established base-line was found, then giving the breakfast, and subsequently continuing the metabolism measurements until the base-line was again reached. Two subjects, a man and a woman, were studied and the student form of respiration apparatus was employed. The results make it quite clear that a meal of this type does not produce any measurable influence upon metabolism and, with normal individuals, can not interfere with basal-metabolism measurements, provided the food is completely eaten at least one hour prior to the tests. It has not been demonstrated, however, that even this small quantity of food might not stimulate further the abnormally high metabolism obtaining in disturbances of the endocrine glands. Tests along this line should be carefully made before permitting the light breakfast in general in pathological cases; but it is believed that ordinarily with normal individuals the sense of euphoria resulting from the warm and satisfying, though light, meal will actually make for less discomfort, less irritability, and ultimately for a greater degree of accuracy in basal-metabolism measurements.

(10) Diabetic metabolism with high and low diets. Elliott P. Joslin. Carnegie Inst. Wash. Pub. No. 323 (1923). 334 pp.

A report is given of metabolism studies with 113 diabetics between the years of 1908 and 1917, which includes not only the data for the 24 patients previously discussed in Publications Nos. 136 and 176, but also the results obtained with 89 diabetics studied subsequent to 1911. The research included 456 experiments with the diabetics in the post-absorptive state and 205 experiments after food.

During the observations a radical change was made in treatment. Prior to 1914 the patients were overfed with a low-carbohydrate and high-protein fat diet. In June 1914 fasting and undernutrition were introduced. The change in the method of treatment so profoundly affected the metabolism of the diabetics as to necessitate the separation of observations into two groups. Before 1914 the post-absorptive metabolism of the 113 patients averaged 12 per cent above normal, but with the low diet after 1914 it was 11 per cent below normal, with a range for all degrees of severity from 32 per cent above to 40 per cent below standard. This difference in the metabolism before and after 1914 was especially apparent with the severe cases. The change was reflected in the pulse-rate, which averaged 73 beats before and 65 beats after 1914.

The acidosis decreased with the change in dietetic treatment, the number of experimental days on which it was present falling from 85 per cent to 67 per cent with the whole group and from 40 per cent to 5 per cent with the severe diabetics. A study of the relation between acidosis and metabolism led to the conclusion that acidosis increases the metabolism. The nitrogen excretion per kilogram of body-weight followed the general trend, in that it was approximately one-third less following the change in diet in 1914. The nitrogen metabolism did not adequately explain variations in the basal metabolism.

Age was found to have a definite influence upon the metabolism of the diabetic. Patients between 51 and 70 years had an approximately normal metabolism, but with individuals between 21 and 50 years of age the metabolism averaged 17 per cent above standard in the early period and 10 per cent below in the later observations.

The respiratory quotient in diabetes was shown to bear a definite relation to the metabolism, being low when the metabolism was high and higher when the metabolism was low, with a general tendency to rise as the metabolism fell. The average quotient before June 1914 was 0.73 as compared with an energy metabolism for the same cases of 13 per cent above standard, while after June 1914 it was 0.77 as compared with 10 per cent below standard for the metabolism. Both extremely low and extremely high quotients were found, the former being due to the ingestion of much protein and fat with little carbohydrate, with some evidence to indicate that the high quotients were due to lack of available fat, necessitating unusual katabolism of body protein or even the transformation of carbohydrate into fat.

The post-absorptive observations upon diabetics were supplemented by similar observations in 1916 upon a healthy individual who underwent for 20 days the treatment then employed for diabetes. The results showed a loss in weight, development of acidosis, decrease in blood sugar, and constant basal metabolism.

A great many of the experiments after food were made with levulose, there being 51 experiments in all with this substance. While the quantities ingested were in the main well utilized, the urines remained sugar-free with the severe cases in but 9 experiments. After levulose the metabolism rose on the average 17 per cent, this increase being slightly greater than that found with normal individuals previously studied by the Laboratory and continuing at a higher level for a longer period of time. The increase was more prominent with the severe cases. The average quotient for the group in the second half-hour after levulose was 0.84. Thereafter it fell steadily and with considerable uniformity until it approximated the basal quotient in the fifth half hour, and in subsequent observations, in contrast with results found with normal individuals, it dropped below the basal quotient.

Other food materials studied were orange juice, dextrose, levulose, and fat, beefsteak and butter, and oatmeal alone and combined with butter. A considerable number of experiments were made after mixed meals. A rise in metabolism was found with all of the food materials. After oatmeal and fat the heat production increased on the average 22 per cent. On the typical "oatmeal days" the metabolism rose from 14 per cent after the first meal to 26 per cent after the fifth meal. An analysis of all of the food experiments showed no special relation between the level of the basal metabolism and the degree of reaction of the body to food. There was no marked variation in the reaction to food with the diabetics as compared with that of normals.

(11) Undernutrition in steers: its relation to digestion, metabolism, and subsequent realimentation. Francis G. Benedict and Ernest G. Ritzman. Carnegie Inst. Wash. Pub. No. 324 (1923). 333 pp.

At the Agricultural Experiment Station at Durham, New Hampshire, 11 adult steers were subjected for 4½ months to a reduction in ration amounting to approximately half of their maintenance requirements. Three other steers served as controls. Subsequently certain steers received fattening rations of hay and grain, while others were put upon pasture. A special respiration chamber was used to measure the carbon-dioxide production of the steers at different nutritive levels. Chemical analyses were made of the hay and different grains, and with two of the steers the composition of the feces and the nitrogen in the urine were determined.

As a result of the curtailment of ration, the steers lost on the average 23 per cent of their body-weight. During the last few weeks of undernutrition the weights of practically all the steers remained at essentially a constant level. On refeeding, large changes in intestinal ballast, due to retained feed residues, resulted in rapid increases in weight. With heavy hay and grain rations or pasturage the steers were readily fattened for market.

The measurement of the carbon-dioxide production of the steers while standing, with minimum muscular activity, and 24 hours after the last feed, gave a basis for the computation of the heat-production. Per square meter of body-surface the 24-hour heat-production at the maintenance level was on the average 2,150 calories. This was subsequently lowered by curtailed rations to 1,475 calories. A rapid return to the original metabolic level followed realimentation with even moderate amounts of feed. It was computed that these steers underwent a 50 per cent reduction in rations for 140 days with a loss to the body of 1,300 grams of nitrogen and approximately 52 kg. of fat. The actual cost in metabolizable energy for each kilogram of body-weight gained during the realimentation period was essentially the same with the undernourished steers (except for the grass-fed steers) as with the control steers. It is concluded that adult steers may be carried through the winter on extraordinarily low rations and subjected to heavy losses in weight without experiencing permanent damage; and that they will be able to regain their original weight and can be fattened for market with subsequent offering of plenty of feed.

(12) Undernutrition and its influence on the metabolic plane of steers. Francis G. Benedict and Ernest G. Ritzman. Proc. Nat. Acad. Sci., vol. 9, pp. 23–25 (1923).

A brief presentation of material published in detail in Publication No. 324 of the Carnegie Institution of Washington.

(13) Human metabolism measurements as a laboratory exercise. Francis G. Benedict and Cornelia Golay Benedict. Printed in the collected Abstracts of Communications to the XIth International Physiological Congress, Edinburgh; July 1923.

A description, with emphasis upon class-room and laboratory usage, of a new respiration apparatus.

(14) The basal metabolism during pregnancy and the puerperium. Howard F. Root and Hester K. Root. Arch. Intern. Med., vol. 32, pp. 411–424 (1923).

Observations of the basal metabolism from the fifteenth week of pregnancy to the eighth week after delivery were made in the case of a primipara in whom pregnancy was uncomplicated by gain of adipose tissue or disease. A steady increase in total calories per 24 hours was observed until 11 days before delivery, when the basal metabolism was 23 per cent greater than that during the fourth month. The gain, expressed as calories per kilogram, was 7.6 per cent. Following delivery the basal metabolism fell gradually to a point 9.6 per cent below that observed during the fourth month of pregnancy. The vital capacity increased steadily from the fifth month onward, with a marked rise in the last month of pregnancy. Standards of basal metabolism for use in practical obstetrics should be developed by the study of normal pregnant women, and a comparison of the basal metabolism of pregnant women should not be made with standards of basal metabolism for non-pregnant women.

(15) Alcohol check experiments with portable respiration apparatus. Thorne M. Carpenter and Edward L. Fox. Boston Med. and Surg. Jour., vol. 189, pp. 551–561 (1923).

A series of alcohol check experiments was carried out with several types of respiration apparatus designed to measure the absorption of oxygen. A special arrangement of a Pyrex burner and housing, a hand spirometer, and a finely divided burette containing alcohol and raised by a kymograph, was used as a mechanico-chemical testing apparatus. With this combination it was possible to reproduce respiration experiments with the various apparatus of the same order of magnitude of oxygen use and breathing volume as with men. The average of a large number of determinations with the Benedict and Collins portable apparatus, using ordinary soda-lime, was 104 per cent of theory. An intensive study of the various factors involved in this apparatus showed that the 4 per cent error was made up of about 0.5 per cent due to the presence of carbon dioxide in the spirometer bell, 2 per cent due to moisture conditions, and the remainder to erroneous measurement of the average temperature. When Wilson soda-lime (a water-rich product) was used and the volumes calculated as saturated, the average was 100.3 per cent. A series of tests with the Roth modification gave an average of 100.2 per cent. The average of a group of tests with the student respiration apparatus of Benedict and Benedict was 100.2 per cent.

(16) Why is a child always hungry? Francis G. Benedict, Hygeia, vol. 1, pp. 519–520 (1923).

A popular presentation of the food requirements of the child.

DEPARTMENT OF TERRESTRIAL MAGNETISM.[1]

LOUIS A. BAUER, DIRECTOR.
JOHN A. FLEMING, ASSISTANT DIRECTOR.

GENERAL SUMMARY.

COMPOSITION OF THE EARTH'S MAGNETIC FIELD.

The present annual report, the twentieth since the establishment of the Department in 1904, is largely devoted to a narration of results obtained from a discussion of accumulated observational and experimental data. As our studies progress, the wide significance and broad bearings of the phenomena of the Earth's magnetism and its electricity are becoming more and more manifest. It would seem not unreasonable to expect that these subjects may contribute facts of interest and importance not alone to the magnetician, but to the physicist, astronomer, and geologist as well.

Preparatory to a lecture, entitled "The greater problems of the Earth's magnetism and their bearings on astronomy, geology, and physics," delivered by the Director at the Carnegie Institution of Washington on November 21, 1922, a preliminary analysis of the Earth's magnetic field for 1922 was undertaken. Owing to the extent and accuracy of the accumulated data, it has become possible to give definite answers to some of the greater questions outstanding. For example, there can now no longer be any question that the Earth's intensity of magnetization has been steadily diminishing during the past 80 years at a rather large average annual rate, namely, about 1/1,500 of itself. Even though no statement at present may be made as to how much longer the diminishing will continue, or as to whether the Earth's magnetism has been steadily running down for centuries past, what has already been found is of profound bearing upon theories as to the origin of the magnetic field enveloping our planet.

About 94 per cent of the Earth's magnetic field is to be ascribed to internal magnetic and electric systems (I), about 3 per cent to external systems (E), or systems in the atmosphere, and the remainder (N), about 3 per cent, to a magnetic system the evoking agencies of which, as, for example, vertical electric currents, may pass from the atmosphere into the Earth and out again. As the result of the N system, the path followed in going around the Earth, let us say eastward, always at right angles to the direction of the compass needle, is generally not a closed curve, i. e., the supposed traveler would at the end of his journey be about 30 miles to the north or south of his starting-place, according to the region of the Earth traversed. Though the E and N systems contribute, as stated, only about 6 per cent to the magnetic force as observed on the Earth's surface, their further study and elucidation may reveal some entirely new facts pertaining to matter, which facts may be also of significance in studies concerning the origin of the Earth's electric field, another great outstanding problem.

The I system—the 94 per cent of the Earth's total magnetic field—exhibits certain characteristics that are of peculiar interest, both to the geophysicist and to the geologist. It is by no means so simple a magnetic system as frequently assumed by those announcing the discovery of a new theory of the origin of the Earth's magnetism.

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[1] Address: Thirty-Sixth Street and Broad Branch Road, Washington, D. C.

The continued studies of the Sun's magnetic field by the Mount Wilson Observatory, combined with those of the magnetic fields of the Earth and the atmosphere by the Department of Terrestrial Magnetism, are resulting in a most interesting array of facts with regard to the magnetic fields of three bodies differing greatly in their physical composition. All three bodies are enveloped by magnetic fields showing some striking general characteristics which seemingly indicate that the origin, strength, and orientation of the magnetic field may be primarily dependent upon direction and speed of rotation and upon size and mass of the rotating body.

Of particular importance also to theories is the precise manner in which the Earth's magnetism and its electricity are affected by variations in solar activity and during solar eclipses; accordingly extensive studies have been made in these directions. Respecting possible eclipse effects, it is noted that the Department's expedition to Point Loma, California, reported that, during the solar eclipse of September 10, 1923, appreciable magnetic and electric effects confirming previous results were obtained.

Enough has been said to indicate, in a general way, the trend of our investigational work in the field and in the laboratory. Fuller statements will be found under their appropriate headings.

COOPERATIVE WORK.

The work done by the Department of Terrestrial Magnetism in cooperation with governmental and other institutions and with individual investigators is extensive and varied. Besides the interchange of magnetic and electric data with hydrographic bureaus, observatories, and magnetic services the world over, the Department has cooperated with the following organizations: the United States Coast and Geodetic Survey, the United States Hydrographic Office, the United States Bureau of Standards (especially in radio investigations), the United States Weather Bureau, the Dominion Observatory and the Meteorological and Magnetic Service of Canada, the British Admiralty (Greenwich Observatory), the Amundsen Arctic expedition, the MacMillan North Greenland expedition, Liberian Boundary Survey, Bermuda Hydrographic Survey, Department of External Affairs of New Zealand in the maintenance of the Apia Observatory in Western Samoa, Commonwealth Weather Bureau and Department of Agriculture of Western Australia, University of Western Australia, Postal and Telegraph Offices of Australia respecting information as to magnetic storms and earth currents, Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union, Commission on Terrestrial Magnetism and Atmospheric Electricity of the International Meteorological Committee, National Academy of Sciences, National Research Council, and American Geophysical Union.

Special reference may be made to the cooperative work with the Institution's archæological expedition to Guatemala under the general charge of Dr. Sylvanus G. Morley. Observer W. A. Love was assigned to the party under O. G. Ricketson, in order to determine the geographic positions and orientations (astronomic and magnetic) of the archæological ruins investigated (see abstract, pp. 261–262).

INVESTIGATIONAL WORK IN WASHINGTON.

The general investigational work, theoretical and experimental, conducted during the year in the Department's laboratory at Washington by the Division of Investigational Work, under the Director's charge, was as follows:

TERRESTRIAL MAGNETISM AND ELECTRICITY.[1]

Analysis of the Earth's magnetic field for 1922, by the Director, assisted by Messrs. W. J. Peters, C. R. Duvall, C. C. Ennis, and Miss Emma L. Tibbetts (see abstract, pp. 248–249).

Magnetic data and charts for polar regions.—The reductions concerned with the analysis of the Earth's magnetic field showed it to be highly important to obtain additional magnetic data for the higher latitudes, both as regards the distribution of the magnetic elements and their secular changes. Accordingly, all available data, for stations north of latitude 50° and south of latitude 40°, were assembled by Messrs. Peters and Duvall and put in tabular form preparatory to the construction of improved magnetic charts for the polar regions, as soon as the attempt may be warranted.

Further investigation concerning line integrals of the magnetic force.—See abstracts, pages 252 and 265.

Relationships between terrestrial magnetism, terrestrial electricity, and sunspot activity.—The studies under this head have been continued and a report on the chief results obtained has been prepared for publication (see abstract, p. 249).

Measure of the Earth's magnetic activity.—See abstract, page 249.

Publication and lecture work.—Good progress was made with various special reports to be published as a volume of the "Researches of the Department." For publications in scientific periodicals and papers before scientific societies, see abstracts on pages 246–266.

Besides the lecture referred to on page 229, the Director gave a lecture on "The general phenomena and theories of the Earth's magnetic field" at the Standardization Laboratory of the General Electric Company at West Lynn, Massachusetts, March 30, 1923, and another on "The present status of our knowledge regarding the constitution and the causes of the Earth's magnetic field" on March 31 at the Research Laboratory of the General Electric Company at Schenectady, New York.

Miscellaneous.—Numerous conferences were held with eminent physicists on various problems pertaining to terrestrial magnetism and atmospheric electricity. On December 8 and 9, 1922, the Director took part, on the invitation of President Merriam, in a conference on the origin and nature of cycles, held at the Carnegie Institution of Washington.

EXPERIMENTAL WORK IN MAGNETISM.[2]

Magnetization by rotation.—Dr. Barnett has been occupied almost entirely with the continuation of the investigation on magnetization by rotation. Much labor has been devoted to reducing the accidental errors, and especially the residual systematic errors. With this object in view, considerable improvement has been made in almost every part of the apparatus. In addition to extended observations on some of the ferromagnetic substances previously studied, it has been possible, through the kindness of the Western Electric Company and the Bureau of Standards, to investigate the behavior of the iron-nickel alloy known as permalloy, remarkable for its great susceptibility in weak fields, and the iron-cobalt alloy introduced by Preuss, remarkable for its great induction in intense fields. In both substances the elementary magnets have, at least approximately, the same ratio of angular momentum to magnetic moment as those of the other ferromagnetic substances investigated. The kindness of the Bureau of Standards and the Westinghouse Electric and Manufacturing Company has also made it possible to prepare rotors of the purest iron, of a cobalt-nickel alloy, and of an additional alloy of nickel and iron. It is expected that observations on these substances will be made soon. The work has been very greatly facilitated by the kindness of the Capital Traction Company, which in February substituted bus service for the part of its night street-car service inaugurated in December on the Chevy Chase line.

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[1] From the reports of Louis A. Bauer and W. J. Peters.

[2] From the report of the chief of the section, S. J. Barnett.

Miscellaneous Laboratory Work.—Mr. Kotterman has devoted most of his time to assistance in the work on magnetization by rotation. He further developed for the Division of Observational and Administrative Work the technique and apparatus for making fine quartz fibers and prepared, as the result of his experience in the past few years, notes on the production of quartz fibers (see abstract on pp. 260–261). He also designed several appliances for special photographic work at the laboratory and installed them after they were constructed in the shop; these have improved greatly the facilities for preparing illustrations for reports on investigations. Detailed memoranda and instructions for the use of the new photographic equipment were prepared by him.

Publications.—In the *Philosophical Magazine* for December 1922, Dr. Barnett published a paper on "Electric fields due to the motion of constant electromagnetic systems," containing the greater part of the material on electromagnetic induction abstracted on pages 285 to 289 of last year's report. He also published a paper on "Magnetization, rotation, and atomic structure" in the *Physikalische Zeitschrift* for January 1, 1923 (see abstract, pp. 247–248). Mr. Kotterman prepared a description of an automatic focusing enlarger, designed and constructed by him, which was published in *Photo-Miniature* for May 1923 (see abstract, p. 260).

EXPERIMENTAL WORK IN TERRESTRIAL ELECTRICITY.[1]

Atmospheric-electric apparatus and instructions for observatories and special expeditions.—Conductivity recording apparatus No. 7 for the Huancayo Magnetic Observatory was assembled and tested in the Laboratory at Washington prior to its shipment to the observatory. The details of this work were attended to chiefly by Mr. W. C. Parkinson (who later installed the apparatus at Huancayo) and by Mr. H. F. Johnston.

Equipment and instructions were prepared for the atmospheric-electric work of the MacMillan North Greenland expedition of 1923 to 1924. The same equipment was provided as used in the MacMillan Baffin Land expedition of 1921 to 1922, but both the apparatus and the procedure were somewhat modified in accordance with experience gained on the previous expedition. Similarly, in the matter of equipment and procedure for the atmospheric-electric observations of the Department during the total solar eclipse of September 10, 1923, care was taken to incorporate, so far as practicable, improvements resulting from the earlier eclipse observations of the Department at Lakin, Kansas, in 1918, and at Sobral, Brazil, in 1919. A large part of the preparatory work in connection with both the MacMillan North Greenland expedition and the California Eclipse expedition was carried out by Mr. H. F. Johnston, who also cooperated with the chief of the section in preparing "General directions for absolute potential-gradient observations."

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[1] From the report of the chief of the section, S. J. Mauchly.

The experimental observatory on the deck of the Laboratory was continued in operation, although the proportion of usable records has temporarily greatly decreased owing to the frequent operation of steam shovels in the vicinity of the Laboratory. Observations were made at stations near by in November 1922 and July 1923 to determine the reduction factor for the potential-gradient electrograph in the deck observatory; the field observations for this purpose have been under the direct charge of Mr. H. F. Johnston, who was assisted at various times by Messrs. O. W. Torreson, R. H. Goddard, W. C. Parkinson, and O. H. Gish.

The detailed design of the recording potential-gradient apparatus for installation at the observatories of the Department was partly completed, and various forms were devised for recording the daily journals and instrument controls required at the observatories in connection with conductivity and potential-gradient observations. The ionium collectors and radioactive resistance cells required for observatory equipment and for the needs of special expeditions and field observations were prepared and tested in the Laboratory. Conducting quartz fibers for the string electrometers so largely used on field expeditions were prepared by Mr. O. H. Gish. In the course of this work the method of preparing the fibers was modified and a mounting device designed, so that now completed fiber systems may be prepared with greater facility and certainty (see abstract, pp. 259–260).

Reduction of atmospheric-electric observations.—A thorough and detailed study of the observations made at various times and places for the standardization of the potential-gradient apparatus aboard the *Carnegie* was completed, thus making it possible to reduce to absolute values the observations which have been regularly made during Cruises IV, V, and VI. Valuable assistance in this work was received from Captain J. P. Ault, who commanded the *Carnegie* during the fourth and sixth cruises.

The observations on the diurnal variation of the potential gradient made aboard the *Carnegie* during the last year of Cruise VI (November 1920 to November 1921) were reduced and the results compared with those obtained from the earlier *Carnegie* observations. The investigation of the diurnal variation was extended to include practically all the available data from land observations (see abstract, pp. 262–263).

Among other reductions carried out during the year were the following: (*a*) The diurnal-variation observations on the conductivity of the air over the oceans from observations aboard the *Carnegie* during 1921 (see abstract, pp. 264–265); (*b*) continuous potential-gradient records from the deck observatory in Washington for the years 1917 to 1922 (see abstract, p. 265), and (*c*) preliminary reductions of the potential gradient at Apia Observatory from May 1922 to April 1923 (see abstract, pp. 263–264).

A large and important part of the computational work involved in the above reductions was performed by Mr. C. C. Ennis and Miss Mary C. Parker.

Polar-light investigations.—Preliminary studies bearing on this subject have been continued, including the preparation of a report presented at the annual meeting of the American Geophysical Union, April 1923.

Progress in earth-current work.[1]—Investigation of the nature and causes of certain "spurious" potentials, or "plate effects," which often enter earth-current measurements, was continued this year in the hope of finding means of diminishing or eliminating this serious obstacle which lies in the way to absolute measurement of earth currents. In connection with this work a method was found of determining quantitatively the contact resistance of individual earthed electrodes (see abstract, pp. 258–259).

The recording instrument designed for use at Watheroo was delivered by the makers in February and was given numerous tests at Washington before sending to Watheroo for installation. As a part of these tests, the instrument was set up at the Cheltenham Magnetic Observatory, where a continuous record was obtained for three days on short earth-current lines. This, besides serving as a further test, would, it was believed, give information as to whether leakage currents from electric railways are of such magnitude at Cheltenham as to exclude the possibility of making measurements of true earth currents there. The records obtained, however, show no conclusive evidence of such an effect.

A system was developed for reducing such earth-current records as are obtained with this recorder, and with the effective assistance of Mr. Ennis the three days of Cheltenham records were reduced and analyzed. A chart was designed, by which the azimuth and magnitude of the earth-current potential-gradient could be found from scaled values (or their departures from a mean value) by a single entry.

Preparation of equipment for the resistivity surveys which are to be made in connection with the Department's earth-current lines is under way, and it is hoped this will be ready for field tests by the end of the present calendar year.

The system for earth-current potential measurements at Watheroo is now furnishing preliminary records. For a description of this sytem, see abstract on page 258. The lines are equipped, however, with only temporary electrodes; the recommendation of a type suitable for permanent installation must await the results of some incomplete investigations.

OBSERVATIONAL AND ADMINISTRATIVE WORK.

The Division of Observational and Administrative Work continued in charge of the Assistant Director. Good progress was made in the field and office work and in the development of the program for observatory work. In the administrative work principal assistance was received from the chief clerk, Mr. M. B. Smith, and from the property clerk, Mr. J. J. Capello.

A bulletin containing information and news regarding personnel, observatory work, field operations, and other items of interest was issued to members of the staff on the average once a month, beginning the end of April.

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[1] From subreport by O. H. Gish, associate physicist.

Land magnetic survey.—The land magnetic work was planned particularly with reference to securing required data concerning the magnetic secular variation and the diurnal variation.

Atmospheric electricity.—The registrations of the electrical conductivity of the atmosphere are now being made at both the Watheroo and Huancayo observatories, in addition to the magnetic registrations for the three elements, and it is hoped that the continuous registration of potential gradient may be undertaken at each of these observatories by the beginning of the new year. Continuous potential-gradient observations and occasional electrical-conductivity observations are being obtained regularly at the Apia Observatory.

Earth currents.— The earth-current installations are complete at the Watheroo Observatory, and this work will be on a satisfactory basis by the new year; it is hoped that corresponding installations and observations may be undertaken at Huancayo some time in 1925.

Computational and publication work.—Good progress was made also in computational and publicational matters, particularly with respect to the ocean magnetic survey accomplished through 1921 on the *Carnegie.* The results obtained indicate most strongly the desirability of resuming at an early date the cruises of the *Carnegie* for the continued investigation of the magnetic field of the Earth and, especially, of its secular variation, of apparent oceanic magnetic anomalies, and of the electric field of the Earth (atmospheric electricity and earth currents).

Cooperative work.—The Department continues to cooperate with other organizations and expeditions and with various governments in advancing important matters within its fields of research.

The satisfactory arrangements made with outside manufacturers for the construction of magnetic instruments for other organizations promise to make it possible to devote an increasing amount of time in the instrument shop to the experimental development of applicances for laboratory and observatory researches.

The final detailed drawings for piers and installation of variometers for exhibit purposes in the new building of the National Academy of Sciences at Washington were completed.

The following abstracts from the reports of the Assistant Director and of the section chiefs summarize briefly the work done during the year.

OCEAN WORK.[1]

Vessel maintenance.—The *Carnegie* remained out of commission at the wharf of the Washington and Colonial Beach Steamboat Company in Washington throughout the year in charge of a caretaker. The housing of the vessel (see p. 274 of last year's report) was completed early in November and has proved entirely satisfactory.

The continued general interest in the *Carnegie* and her work was evidenced by the many visitors who, during the year, asked to inspect her, even though she was out of commission.

Final reductions of observations at sea.—The final computation and summaries of ocean magnetic results from 1915 to 1921 and the manuscript to accompany these final results, to be published as one of the volumes of the "Researches of the Department," were completed in October by the chief of the section. The principal assistance in this work was received from Mr. H. F. Johnston.

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[1] From the report of the chief of the section, J. P. Ault.

The reductions and analyses of the ocean data necessary in the preparation of the manuscript above referred to emphasize that, in order to reap the full benefit of the work already accomplished at sea, plans should be considered to resume soon the ocean surveys of the *Carnegie*, and thus take advantage of the remaining useful life of a vessel specially adapted for magnetic and electric surveys at sea. In this connection attention may be called to the following resolution, passed at the General Meeting of the Second Pan-Pacific Science Congress, which was held at Melbourne and Sydney, Australia, August 13 to September 3, 1923:

> "That this Congress desires to place on record its appreciation of the investigations, valuable to geophysicists and navigators, that have been carried out on board the nonmagnetic survey yacht *Carnegie*, and expresses the hope that it will be possible to continue this work by the magnetic exploration of fresh ocean areas and by the determination of the secular variation of the magnetic elements."

Early in the year Mr. W. J. Peters, in command of the Hudson Bay expedition of 1914, completed the reductions of the ocean magnetic observations and the manuscript of the report on that expedition; this article will be published as a special report in the volume containing the final ocean magnetic results secured aboard the *Carnegie* during 1915 to 1921.

Observational and miscellaneous work.—The completion of the manuscript for the final results of the ocean observations during 1915 to 1921 permitted undertaking but a limited amount of other work. The ocean-current data obtained during the six cruises of the *Carnegie* were tabulated and forwarded to the United States Hydrographic Office for use in preparing a new chart on ocean currents.

The chief of the section, assisted by Mr. Johnston, made special magnetic and electric observations at Point Loma, California, during the total solar eclipse of September 10 (see p. 252). Upon the completion of the observational program at Point Loma, Captain Ault attended the Los Angeles meeting of the American Association for the Advancement of Science and presented two papers before meetings of sections B and D on (1) Magnetic results obtained on the *Carnegie* during Cruises IV, V, and VI, 1915–1921, and (2) Effects of a total solar eclipse on the Earth's magnetic and electric fields (see abstract, p. 247).

In connection with the study of the development of instruments for use in aircraft, the chief of the section attended the December 1922 meeting in New York City of the Aeronautic Division of the American Society of Mechanical Engineers and took part in the discussion of the papers on air navigation. He presented a paper on air navigation before the Philosophical Society of Washington (see abstract, pp. 246–247).

LAND MAGNETIC SURVEY.[1]

Program for field observations of magnetic changes.—Field work has been devoted chiefly to determining the changes taking place, both secular and diurnal. Except for a few stations in Haiti and the Dominican Republic, and those on expeditions up the Xingu and Trombetas Rivers, tributaries of the Amazon, practically all the stations occupied have been those at which observations had been previously made, either by observers of this Department or of other organizations. In general, the reoccupations were sufficiently exact, and the time interval since the last occupation of such duration that satisfactory data for determining secular variation were secured.

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[1] From the report of the chief of section, H. W. Fisk.

To extend our knowledge of the diurnal variation in the three magnetic elements beyond that obtained by the existing and widely scattered magnetic observatories, the special diurnal-variation program was developed further to include such work for inclination and horizontal intensity as well as declination at field stations. At selected stations from 500 to 800 miles apart and designated as Class I stations, observations were made to determine the diurnal variation during the daylight hours in horizontal intensity by means of deflection observations at one distance, repeated at short intervals; the method followed gives also the variation in declination as well. On a succeeding day repeated observations with the earth inductor are made from which the diurnal changes in inclination are derived. At Class II stations the usual program of observations is repeated on successive days, the observer endeavoring to so select the time of observations that a value of each element may be obtained near the time of its daily maximum and its daily minimum.

Field operations.—Three observers have continued in the field throughout the entire year and a fourth since the end of December. With the exception of two months spent in the Pacific Islands, Mr. Coleman continued in Australia; Mr. Green, after work along the north coast of Venezuela, proceeded southward through eastern Brazil to Argentina, and thence overland through Bolivia to Peru; Mr. Howard, who joined Mr. Green in January and accompanied him as far as the mouth of the Amazon, worked thence along that river and its tributaries; Mr. Love, after an expedition into Colombia, South America, returned to Guatemala and other Central American states. Mr. Goddard joined the MacMillan North Greenland expedition on June 9, with which he continued throughout the year. (See also cooperative work with the Liberian Boundary Survey, p. 240.)

A brief synopsis of the year's work on these various expeditions follows:

1. *Australasia.*—After completing his work in connection with the eclipse of September 21, 1922, Observer D. G. Coleman reoccupied stations in Queensland, Australia, along the railways leading inland from Brisbane and Rockhampton. After spending the months of November and December in the Pacific islands, he took up work in Tasmania, arriving on January 19; after reoccupying stations at Latrobe, Longford, Hobart, Sorell, and Southport, he returned on February 12 to Melbourne, New South Wales. From Melbourne he proceeded to South Australia, making comparison of his instruments with the standards of the Adelaide Observatory at Mount Lofty in the latter part of February. After reoccupying four additional stations in South Australia, he proceeded to Watheroo, where he compared his instruments with those of the Watheroo Observatory during April 5 to 10. On his return from Watheroo, he met Mr. Kennedy, of the South Australia Observatory, at Port Augusta, where comparisons were again made with the instruments of the Adelaide Observatory, He then proceeded through South Australia and New South Wales, reoccupying stations including Oodnadatta and Burke, to Red Hill, near Sydney. His next work was in northern Queensland and the York Peninsula; he arrived at Thursday Island September 5,

and at Port Darwin September 14. Upon the completion of the work in northern Australia he observed at several secular-variation stations in the East Indies and obtained comparison observations at the magnetic observatory at Batavia, Java, while en route to Washington.

Cooperation has been continued throughout the year with the government astronomer of South Australia, Mr. G. F. Dodwell, and his chief assistant, Mr. A. L. Kennedy, who reoccupied some of the earlier stations of the Department, in connection with the observatory work.

Absolute observations, as well as continuous photographic registrations of the three magnetic elements, were made throughout the year at the Watheroo Magnetic Observatory (see pp. 240–241).

2. *North America.*—After completing his work in Colombia in January, Mr. Love returned to Jamaica and thence proceeded to Belize, British Honduras, to carry out a plan of cooperation with the Mid-American Archæological Expedition of the Carnegie Institution of Washington, directed by Dr. S. G. Morley. This expedition was equipped by the Department with a portable wireless receiving apparatus and light theodolite for astronomical observations in order to fix with a precision of one-half mile the geographic positions for eleven sites of Maya ruins under investigation. At the same time, magnetic observations were made at eight stations in British Honduras and northern Guatemala. The expedition left Belize, British Honduras, on February 17, entering Guatemala at El Cayo, and traversed the country to Flores on Lake Peten and the region in northeastern Guatemala, north of these points, returning to Belize on April 28. (For abstract of report on results obtained, see pp. 261 to 262.) At the conclusion of this work, Mr. Love resumed the reoccupation of stations in Central America, going by way of Puerto Barrios and Puerto Cortez to Trujillo, Honduras. Difficulties in transportation made it necessary to omit the stations along the coast and proceed directly to Port Limon, from which stations in Nicaragua, including Bluefields, Prinzapulca, Greytown, Granada, and Managua, were easily reached. He made observations at Guatemala City in accordance with the special program for the solar eclipse of September and then continued observations at secular-variation stations in Guatemala, Panama, and Costa Rica.

Special magnetic and atmospheric-electric observations were made at Point Loma, California, during the eclipse of September 10 by a party organized by Captain J. P. Ault, assisted by Observer H. F. Johnston, the latter having charge of the atmospheric-electric observations. Magnetic observations were also made by Captain Ault at Mount Wilson, and the special eclipse program in declination was carried out by Dr. Gustav Strömberg, of the Mount Wilson Observatory, assisted by Mr. Thomas Mulvin.

In cooperation with Captain Donald B. MacMillan, Observer R. H. Goddard was assigned as a member of the MacMillan North Greenland expedition, which left Wiscasset, Maine, on June 9, for Etah, North Greenland, and Ellesmere Land. Mr. Goddard made magnetic observations on the outward voyage at Sydney, Nova Scotia, and at Battle Harbor and other points on the Labrador coast. According to the latest radio advices (November 10), observations were made by Mr. Goddard at Godhavn, Etah, and Refuge Harbor, Greenland, and the temporary observatory for magnetic and electric registrations, beginning October 19, was built at the last-named station.

Cooperative magnetic and atmospheric-electric work with the *Maud* expedition of Captain Amundsen (see p. 276 of last year's report) during the drift of the *Maud* across the Polar Sea was continued. According to radio advice received December 1, the *Maud* was then in latitude 75° 13′ north and in longitude 159° east, and the observational work, in charge of Dr. H. U. Sverdrup, was progressing splendidly.

3. *South America.*—After completing his work in Haiti, Observer J. W. Green arrived at Maracaibo, Venezuela, on November 20, and proceeded along the coast of Venezuela, reoccupying seven stations, including Caracas. At Port of Spain he was joined by Observer J. T. Howard, and after work in Trinidad and the British West Indies, they proceeded up the Orinoco River. Owing to the low stage of water, they were unable to go beyond Ciudad Bolivar and it was necessary to return to Port of Spain. They arrived at Georgetown, British Guiana, on March 5, reoccupying six stations in the three Guiana colonies. The party reached Para, Brazil, on April 16, whence Mr. Green proceeded alone southward through eastern Brazil, reoccupying stations near the coast established by the Department and by the Brazilian Commission. He arrived at Rio de Janeiro on June 26 and compared his instruments with those of the Observatory of Vassouras. He next proceeded to Buenos Aires, and after reoccupying three stations in Argentina, including comparison observations at the Pilar and La Quiaca observatories, he occupied repeat stations in Bolivia and Peru, and arrived at Huancayo September 1. Upon completion of comparisons between his outfit and the standard instruments of the Huancayo Magnetic Observatory, he returned to Washington in September, where the comparisons of his instrument with the standard Carnegie Institution of Washington instruments were completed in October.

Mr. Howard, after leaving Mr. Green's party at Para, Brazil, organized an independent expedition up the Xingu River, a southern tributary of the Amazon, leaving Para on May 9, and proceeded by launch and canoe southward to about 8° south latitude on Rio Fresco, at the edge of the great plains of Central Brazil. On this expedition he occupied eight new stations, and returned to Para on July 13. After establishing several new stations on the island Marajo, at the mouth of the Amazon, he left about the middle of August for an expedition on the Trombetas River, upon the completion of which he expected to reoccupy old stations along the Amazon River westward to Manaos.

After completing his work in Cuba and Jamaica, Observer W. A. Love proceeded by way of Colon to Cartagena, Colombia, thence up the Magdalena River to Bogota and Honda, and thence overland to Buenaventura. This expedition was made during November 3 to January 15, when Mr. Love went to Belize by way of Panama and Jamaica to take up the special work in Guatemala, referred to above.

Absolute observations and continuous photographic registrations of the three magnetic elements were continued throughout the year at the Huancayo Magnetic Observatory (see p. 241).

4. *Islands, Atlantic Ocean.*—After occupying 11 stations, supported by auxiliary stations, in the island of Haiti and Dominican Republic, Observer J. W. Green embarked on November 10 for Curaçao, Dutch West Indies, where a station was reoccupied. After work in Venezuela, he arrived at Port of Spain, Trinidad, on January 15, where he was joined by Observer J. T. Howard. After reoccupying station Port of Spain and others established by the Department in 1905, in cooperation with the Department of Surveys of Trinidad, they established new stations in other parts of the island. The stations in Bridgetown, Barbados, and Kingstown, St. Vincent, were also reoccupied.

5. *Islands, Pacific Ocean.*—Observer D. G. Coleman left Sydney, New South Wales, on November 9 to reoccupy stations established in 1914 in New Caledonia, Loyalty Islands, and the New Hebrides. After reoccupying 11 of these stations, including Noumea and Bourail in New Caledonia, and Lord Norfolk Island, he returned on January 14 to Sydney.

Survey control at Washington and cooperative work.—Considerable time was required to plan the work undertaken, to test and standardize outfits, to coordinate the Department's field activities with those of other organizations so as to prevent duplication, and to arrange for cooperative work with exploratory expeditions. In addition to the cooperation with special expeditions referred to under the head "Field operations," arrangements were made also with Mr. L. C. Daves, chief engineer of the Liberian Boundary Survey, to obtain magnetic observations at stations on the Liberian boundary. He and Mr. C. T. Bussell, his chief assistant, were instructed during November and December in the use of the magnetometer and dip circle and a complete outfit for magnetic observations was supplied.

Reductions of field observations.—The necessary computations and revisions of observations and the preparation of manuscript giving the results of land magnetic observations during 1921 and 1922 were about 90 per cent completed at the end of October; this work was carried out by Mr. Fisk, with the assistance of Mr. F. C. Brown, temporary computer.

The land magnetic results of the MacMillan Baffin Land expedition of 1921 to 1922 were revised and compiled, chiefly by Mr. H. F. Johnston. A general account of the geophysical work of the expedition, including a summary of the results, was prepared by Mr. Fleming for publication as an appendix to Dr. MacMillan's narrative.

Excellent progress was made in the compilations of the extensive observations of the Bermuda magnetic survey of 1922, and papers were prepared on (*a*) the magnetic survey of Bermuda and (*b*) the Bermuda magnetic anomaly and possible effect on secular changes (see abstract, pp. 253–254). In connection with these compilations, Mr. Fisk took up an investigation of methods to determine, by least squares, from observed ocean data, the normal distribution over large areas, in this case that between 24° and 40° north latitude and between 284° and 306° east longitude; a note on this investigation and a suggested method of adjustment is abstracted on pages 254 to 255. The detailed data resulting from the survey were supplied Captain H. P. Douglas, R. N., in charge of the Bermuda Hydrographic Survey under the auspices of the British Admiralty, at his request.

OBSERVATORY WORK.[1]

The following abstracts summarize briefly the work done at the observatories and at Washington:

Watheroo Magnetic Observatory, Western Australia.—Dr. G. R. Wait continued in charge of the observatory throughout the year, with the assistance of Mr. J. Shearer, observer, and, since November 29, also of Mr. J. E. I. Cairns, observatory aid. The magnetographs and conductivity apparatus No. 6 for recording both positive and negative conductivity of the atmosphere were in continuous operation. The installations of two overhead earth-current lines, each 2 miles long, and of two underground earth-current lines, each a mile long, the two systems paralleling each other from the southwest corner of the site to the north and to the east, respectively, were completed; the necessary recording apparatus was installed in the atmospheric-electric and earth-current house. It is hoped that this equipment will be regularly in operation before the close of the year. The program of limited meteorological observations was continued and data were supplied monthly, as in the past, to the Commonwealth Weather Bureau of Western Australia. Comparisons between the standard instruments of the Observatory and Carnegie Institution of Washington magnetometer-inductor No. 24 were made in April.

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[1] From the reports of J. A. Fleming, assistant director, and of the observers in charge.

Monthly tabulations of data, statements of the magnetic character of days as recorded at the observatory, and reports on magnetic storms and earthquake shocks recorded on the magnetograms were forwarded regularly (see p. 266).

In conjunction with the State Department of Agriculture of Western Australia, certain agricultural experiments have been undertaken. A telephone line connecting the observatory with the exchange at Watheroo was completed. Some experiments were made as to an economical type of road construction, but it appears that the purchase of a caterpillar type of automobile is the most feasible solution of the problem of more rapid transportation between the Observatory and the railway station at Watheroo; a whole day is now required for the round trip of 24 miles, using a horse-drawn vehicle.

Dr. Wait, as a delegate from the Institution, attended the Second Pan-Pacific Science Congress at Melbourne and Sydney August 13 to September 3, and presented a paper on the equipment and work of the Watheroo Magnetic Observatory (see abstract, p. 266). It is gratifying to record the continued cordial attitude towards the Observatory of the government officials and leading men of science of Western Australia. Free entry was accorded for all equipment and apparatus.

Huancayo Magnetic Observatory, Peru.—The observatory continued in charge of Mr. W. F. Wallis through June 30, when Mr. W. C. Parkinson succeeded him. Mr. C. M. Little continued to serve as assistant observer throughout the year. The magnetographs were in continuous operation and functioned with scarcely any loss of trace. The daily meteorological observations were continued. The duplex recording apparatus for photographic registration of both the negative and the positive electrical conductivity of the atmosphere was received at the observatory in June and installed in the specially designed observatory; continuous recording was begun in September. Other new instrumental installations included a mercurial barometer mounted in the office, a Jordan sunshine recorder, and a United States Navy type of wireless receiving apparatus, together with aerial and appurtenances for the reception of wireless time-signals.

Monthly tabulations of data, statements of the magnetic character of days as recorded at the observatory, and reports on magnetic storms and earthquake shocks recorded on the magnetograms were forwarded regularly (see p. 266).

The atmospheric-electric and earth-current house, constructed of concrete, following the same design as that at Watheroo, was completed early in February. A concrete house of four rooms, including servants' room, storeroom, room for electric plant, and workshop, was completed. A Delco electric-lighting plant and a Delco shallow-well water system were installed.

Valuable aid was rendered by local residents, the United States embassy at Lima, and by the Peruvian government, which granted free entry of all equipment and apparatus.

Apia Observatory, Western Samoa.—Cooperation with the New Zealand government at the Apia Observatory was maintained throughout the year. During October and November Professors Marsden and Sommerville, of New Zealand, inspected the observatory on behalf of the New Zealand Scientific Honorary Board of Advice and the Department of Terrestrial Magnetism. Beginning with January 1, Mr. Andrew Thomson, the Department's representative, was asked by the Board to serve as acting director of the observatory, with the aid of Mr. C. J. Westland as chief assistant.

Continuous records with a Benndorf recording electrometer of the potential gradient of the atmosphere at the station on the mainland were obtained with comparatively small loss throughout the year. A second Benndorf recording electrometer for registration of potential gradient was installed during August in the small, specially designed house built at the expense of the Department inside the reef about one-third mile off shore. Mr. A. Tyndall, engineer in charge of the Public Works Department of Western Samoa, looked after the designing and construction of this special house, which has been found satisfactory in every way. To control reduction-factor determinations for the equipment at this station, an automatic tide-gage after the design of the United States Coast and Geodetic Survey was ordered. Occasional diurnal-variation observations of the conductivity of the atmosphere were secured.

In addition to the observatory magnetic work by Mr. Westland and the atmospheric-electric work by Mr. Thomson, the latter has maintained, under the auspices of the New Zealand government, an enlarged program of meteorological work, so that now the Apia Observatory serves as the central station of a service embracing the Fiji, Tonga, Marshall, and New Hebrides islands. Mr. Thomson also initiated the resumption of upper-air work, the first pilot-balloon flights being made in June. Cooperation in this work was extended by the United States Weather Bureau and the Canadian Meteorological Service, the former placing on indefinite loan at Apia balloon-filling equipment and pilot-balloon plotting board, while the latter supplied an additional theodolite.

The New Zealand government authorities continued unabated pronounced interest in the maintenance of the observatory. As in past years, all equipment and apparatus were admitted free of duty.

MacMillan North Greenland expedition.—In view of the successful cooperation with the MacMillan Baffin Land expedition of 1921–22 (see p. 278 of last year's report), advantage was taken of the opportunity presented to cooperate with Dr. MacMillan on his North Greenland expedition of 1923–24, which left Wiscasset, Maine, on June 23. The expedition was equipped by the Department with the requisite magnetic instruments for absolute and photographic work, and with the apparatus for registering the electric potential gradient of the atmosphere at a temporary observatory constructed at Refuge Harbor, Greenland, near the quarters for the winter of 1923–24, in latitude 78° 31′ north and longitude 72° 27′ west. The program includes also observations with respect to northern lights, meteorology, tides, and the occupation of magnetic stations in Labrador, Greenland, Ellesmere Land, and Baffin Land. Mr. R. H. Goddard, observer of the Department, has immediate charge of the scientific work.

Maud expedition, 1918 to 1921.—Since last year's report, there was received through the Norwegian legation at Washington, on March 31, 1923, the package containing magnetic records, copies of absolute observations, and original declination magnetograms covering one season's work, originally intrusted to Knudsen and Tessem, members of Amundsen's party, who were lost in 1919 during the return journey to Dickson Island. The records were recovered by the Russian explorer Begitsjer on his expedition of 1921 to 1922. The absolute observations have been already reduced[1] (see pp. 307–308 of last year's report). The magnetograms were obtained at the first winter quarters during October 1918 to August 1919, in latitude 77° 32′.6 north and longitude 105° 40′ east of Greenwich; the compilations from the records at so high a latitude will contribute valuable data for studies of the diurnal variation and of magnetic storms.

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[1] H. U. Sverdrup and C. R. Duvall, Results of magnetic observations on the *Maud* expedition, 1918–1921. Terr. Mag., vol. 27, 35–56 (March–June 1922).

Washington, District of Columbia.—The investigations and control of magnetic standards in the Standardizing Magnetic Observatory at Washington were continued throughout the year. Extensive series of comparisons were made during February and March between sine galvanometer 1, standard magnetometer 3, and magnetometer inductor 27, the last being the instrument so extensively used for observatory comparisons in 1922 (see p. 279 of last year's report). The results indicate that the provisional International Magnetic Standard, adopted by the Department for horizontal intensity in 1914, is in substantial agreement with intensities determined electromagnetically by the sine galvanometer (see p. 256); the 1923 results also confirm the constancy of the adopted standard, as they are in practical agreement with those obtained in June and August 1921.[1] The 1923 series afforded also an indirect comparison of standards with the Schuster-Smith magnetometer (electromagnetic) of the National Physical Laboratory, Teddington, England, and with the Watanabe electric magnetometer of Japan through the comparisons with C. I. W. standardized magnetometers made by Messrs. Parkinson and Brown in 1922 at Teddington and Kakioka. The results, abstracted on page 257, furnish additional evidence of the constancy within all practical and theoretical requirements of the Department's standard in intensity. The compilations of the extensive comparisons obtained at 23 magnetic observatories in different parts of the world during 1922 were finally completed and prepared for publication by Messrs. Fleming and Parkinson. Further comparisons of standards were made in 1923 by Department observers at the following observatories: Apia, Samoa; Batavia, Java; Huancayo, Peru; Kakioka, Japan; Mount Lofty (Adelaide Observatory), South Australia; Pilar and La Quiaca, Argentina; and Watheroo, Western Australia.

At its annual meeting in April 1923, the American Geophysical Union passed the following resolution:

> "That the American Geophysical Union designate the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey and the Standardizing Magnetic Observatory of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, working in conjunction, as the observatories in the United States to function in accordance with resolution No. 4 adopted by the International Section of Terrestrial Magnetism and Electricity at its Rome meeting in 1922." [2]

The experimental atmospheric-electric observatory on the deck of the Laboratory at Washington was continued in operation throughout the year (see abstract of results, p. 265).

Miscellaneous.—Besides the extensive cooperative work already mentioned elsewhere, the Department cooperated with Professor W. Uljanin, of Kazan University, Russia, in his development of electromagnetic instruments, supplying him with normal cells and standardization certificates from the Bureau of Standards.

Reduction of observatory records obtained at the Watheroo Magnetic Observatory, 1919–21.—Dr. H. M. W. Edmonds, with the assistance since September of Mr. W. F. Wallis, has completed about three-fourths of the final compilations from the magnetic data for the Watheroo Observatory during the years 1919 to 1921. He also did some experimental work in the Laboratory at Washington to check the adopted formula for the scale-value for the declination variometer (see p. 252).

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[1] See Res. Dep. Terr. Mag., vol. IV, pp. 416–417.

[2] "That national committees be requested to designate, if possible, one observatory in their respective countries for international intercomparisons of magnetic instruments, and to secure intercomparisons of magnetic instruments within their own countries at least once within the course of three years."

MAGNETIC AND ALLIED OBSERVATIONS DURING TOTAL ECLIPSE OF SEPTEMBER 10, 1923.

A program of desired observations was prepared by Messrs. Bauer and Fleming (see p. 252) and supplied to various expeditions and observatories. The Department established stations for special magnetic and atmospheric-electric observations at Point Loma (within the belt of totality) near San Diego, California, and for magnetic observations at Mount Wilson and at Guatemala City, Guatemala (see p. 238). The director of the United States Coast and Geodetic Survey cooperated in this work by having special observations made at five observatories of that Survey and at a field station near Lompoc, California, within the belt of totality. Professor Joaquin Gallo, director of the National Observatory of Mexico, arranged for special magnetic observations at his astronomical station at Yerbaniz, within the belt of totality, and for a special program by the Mexican magnetic observatory at Teoloyucan. In addition, special observations were made by the Department observatories at Huancayo, Peru, and at Watheroo, Australia, and the Japanese observatory at Kakioka also had planned to cooperate. Information was received that numerous other institutions and observatories, including the Agincourt and Meanook observatories of the Canadian government, would arrange for special observations in accordance with our published program.

INSTRUMENT WORK AND BUILDINGS.[1]

Classification of work.—The heaviest demand on the instrument shop was for the construction of experimental apparatus, fully one-third of the entire time being given to such work. Something less than one-quarter of the time could be given to the design and construction of new instruments and equipment. Improvements and repairs primarily of instruments for field and observatory use and, to a lesser degree, of buildings, engaged something more than one-quarter of the time. Miscellaneous activities, including preparation of detailed drawings, maintenance of stock parts, and renewal of supply of nonmagnetic castings for instruments, and special work, took one-sixth of the available time.

New work.—The principal new instruments and equipment completed during the year and in construction at the end of the year, together with the necessary detailed designs and drawings, included the following: (1) bifilar string electrometers, after Department design, Nos. 19 to 30, completed; (2) construction of two clock, automatic, mercury-contact switches for the earth-current installations at Watheroo; (3) construction of six magnetogram prickers for observatory use to control effectively the shrinkage-correction factors for records from photographic recording devices; (4) construction of two earth-inductor attachments for dip circles; (5) construction and installation of collimating system with controlled shutter for azimuth pier of standardizing magnetic observatory; (6) latern-slide cabinet with special sliding frames for classifying and dust-proof storing of 900 slides; (7) apparatus for assembling of bifilar and unifilar quartz-fiber systems of electrometers; (8) partial construction of three standardized potential-gradient apparatuses with photographic registers for observatory use; (9) five earth-inductor attachments for theodolite magnetometers in stock were begun to make it possible in future to discontinue use of dip circle in favor of the earth inductor, except in Arctic and Antarctic regions, where the dip circle is more convenient for determination of intensity and declination than the magnetometer and less subject to uncertainty for the determination of inclination than in the lower magnetic latitudes.

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[1] From reports of J. A. Fleming, asst. director, and of C. Huff, foreman of instrument shop.

Experimental work.—Three-quarters of the time devoted to experimental apparatus was in connection with the equipment for the special investigation by Dr. Barnett on magnetization by rotation (see p. 247). Other experimental work included parts and apparatus for the proper designing of atmospheric-electric instruments and equipment for field and observatory use and the assembling for test of standard conductivity apparatuses 7 and 8 for observatory use. A 90-pound, nonmagnetic brass bedplate for the equipment in the experiment building was cast in the Department's foundry, and over 1,200 nonmagnetic brass and bronze castings for magnetometer inductors of Department design were made in a local foundry under the supervision of the shop foreman.

Improvements and repairs.—All instrumental equipments for the field parties dispatched during the year (see report on field operations), including those for the party of the Liberian boundary survey and the extensive magnetic and electric equipments for the MacMillan North Greenland expedition and for the special eclipse party at Point Loma, were thoroughly overhauled, modified, repaired, and readjusted as necessary. The dip circles, theodolite, sextant, and other field instruments for the MacMillan North Greenland expedition were provided with celluloid caps for all parts that must be handled with the fingers or which may touch the face during operations, this having been indicated a desideratum through the experience both on the *Maud* expedition of 1918 to 1921 and on the MacMillan Baffin Land expedition of 1921 to 1922. Desirable modifications and improvements indicated by the laboratory tests of conductivity apparatus No. 7, both in the instrument and its appurtenances, were made and corresponding parts provided for apparatuses Nos. 6 and 8. Improvements were made in the photographic equipment, including provision for increased lighting arrangements, specially designed attachments, and facilities for enlargements and photographing of equipment, etc. Shop-lighting units were changed to increase lighting efficiency.

Miscellaneous.—The detailed drawings for field and observatory instruments and for the various observatory buildings were maintained current according to the structural and instrumental developments.

The wireless equipment of the U. S. Navy type for wave-lengths 600 to 25,000 meters was tested and attachments for use in the field supplied before shipping to Belize for the special work in Guatemala (see p. 238). Upon its return it was thoroughly overhauled, retested, and supplied with appurtenances for its proper installation at the Huancayo Magnetic Observatory, where it was shipped in October. The necessary instructions for field use and for installation at the observatory were prepared by Messrs. Johnston and Huff. A macadamized roadway from the main laboratory to the foundry and storehouse was completed.

MISCELLANEOUS ACTIVITIES.

American Geophysical Union.—Various reports and papers were prepared and presented by members of the Department at the annual meeting of the Union in Washington, April 17 to 19, 1923. The following members of staff are among the officers of the Union: Louis A. Bauer, chairman of the American Geophysical Union and vice-chairman of the Section of Terrestrial Magnetism and Electricity; J. P. Ault, chairman of the Section of Oceanography. Mr. Fleming, as secretary of the Section of Terrestrial Magnetism and Electricity, prepared, for publication by the National Research Council, the reports and abstracts of papers presented before the meeting of that section; also, as acting chairman of the committee on meetings, he had charge of all arrangements for the annual meeting of the Union and its sections.

International Geodetic and Geophysical Union.—As secretary and director of the Central Bureau of the International Section of Terrestrial Magnetism and Electricity, Dr. Bauer issued, under his editorship, Bulletin No. 3 of the section, containing the transactions of the Rome meeting, May 1922. Various reports appear in this bulletin by Messrs. Bauer, Fleming, and Mauchly.

Commission on Terrestrial Magnetism and Atmospheric Electricity of the International Meteorological Committee.—The data pertaining to magnetic character of days as determined from the magnetograms at the Watheroo and Huancayo observatories were forwarded regularly to Dr. Van Dijk, of the De Bilt Observatory at Utrecht, for publication by the Commission.

National Research Council.—Messrs. Ault, Barnett, Bauer, Fleming, Mauchly, and Peters have performed various duties in connection with committees of the council and have supplied information on specific topics as requested from time to time. Dr. Barnett is chairman of the Committee on Theories of Magnetism of the Division of Physical Sciences.

Library work.—Mr. Harradon, librarian-translator in charge of the library, reports that over 700 books and pamphlets were received from all sources during the year, making the total number of accessioned publications now in the library of the Department nearly 12,700. In addition to a large amount of translation for various purposes, numerous reports and articles in foreign languages were edited and prepared for publication, particularly in connection with the transactions of the International Section of Terrestrial Magnetism and Electricity. A list of recent publications, under the headings (*A*) Terrestrial and Cosmical Magnetism, (*B*) Terrestrial and Cosmical Electricity, and (*C*) Miscellaneous, was prepared regularly and published in the *Journal of Terrestrial Magnetism and Atmospheric Electricity.* During the latter part of the year, Professor J. D. Thompson elaborated the system of library classification devised by him for the use of the Department in 1904 along lines indicated by his recent examination of the card index of the library. This extended classification was put into effect and a general rearrangement of the library begun.

ABSTRACTS OF PUBLICATIONS AND INVESTIGATIONS.

Sailing the seven seas in the interest of science. J. P. Ault. Nation. Geog. Mag., vol. 42, 631–690 (December 1922).

This paper, illustrated by numerous photographs, gives a popular narrative of the third, fourth, and sixth cruises of the *Carnegie* under command of the author. Following a general statement describing the chief purpose of the cruises, namely, the accumulation of accurate data regarding the Earth's magnetic and electric fields over the oceans, a brief résumé of each cruise is given, with details concerning the routes traversed, covering about 157,000 miles, as shown on an outline chart. Descriptions of the widely varying oceanographic conditions from the high latitudes reached (80° north to 60° south) to the tropical seas are given.

Air navigation.[1] J. P. Ault.

Up to the present time in air navigation dead reckoning has been mostly used. For cross-country flying and short flights over the water, a good compass and a good map are the two most important instruments required, but for long-distance flying the aviator should be able to locate his position, for example, by astronomical observations or directional radio bearings, when he is unable to see objects on the ground during night flights or while flying above clouds or fog. The paper describes work during the latter months of 1918 at Langley Field in the attempt to develop methods and instruments for navigating airplanes by astronomical observations (see Year Book for 1919, pp. 302–304). But owing to difficulties of navigation by astronomical methods and to the fact that frequently no celestial body can be seen, a third method of navigation by some directional radio device seems to be the most promising solution of the problem. This method is as yet in the experimental stage.

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[1] Presented before the Philosophical Society of Washington, May 5, 1923; see Jour. Wash. Acad. Sci., vol. 13, 334, 335 (August 19, 1923).

Effects of a total solar eclipse on the Earth's magnetic and electric fields.[1] J. P. Ault.

The occurrence of a total solar eclipse furnishes an opportunity to study variations in the Earth's magnetic and electric fields which may be caused by a definite known phenomenon. Thus, data may be obtained which will be of assistance in the solution of outstanding questions in terrestrial magnetism and atmospheric electricity.

The first determined and systematic attempt to ascertain whether there was an appreciable effect on the Earth's magnetism during a solar eclipse was made in 1900, at Dr. L. A. Bauer's initiative and under his direction. A large mass of valuable data has been obtained during the various total solar eclipses since that date, chiefly through the efforts of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. Observations of the variations in atmospheric electricity during a solar eclipse were made as early as 1898, but only in recent years has the attempt been made to obtain systematic and extensive electric observations during solar eclipses.

The magnetic and, in part, the electric effects during solar eclipses which may be predicted by theoretical considerations have been verified to a remarkable degree by the observational results. The conclusion seems to be justified that the screening of a part of the Sun's radiation from the Earth's atmosphere due to the Moon's presence between the Sun and the Earth interrupts the march of the usual daily variation in the Earth's magnetic field. The effect, though quite small, has been positively identified in cases when conditions were favorable, e. g., absence of cosmical magnetic storms. The magnitude of the effect depends upon the length of maximum obscuration, distance from the belt of totality, and position of the station in the portion of the Earth covered by sunlight at the time of the eclipse.

The preliminary discussion of the results obtained during the eclipse of September 10, 1923, at Point Loma, at Mount Wilson, and at Guatemala City, confirms previous conclusions regarding possible eclipse magnetic and electric effects.

Magnetisierung, Rotation, und Atomstruktur. S. J. Barnett. Physik. Zs., vol. 24, 14 (January 1923).

In the *Physikalische Zeitschrift* for August 1, 1922 (p. 307), W. Braunbek develops a theory of rotation by magnetization on the assumption that the nucleus is involved as well as the outer electron system, for each orbit of which the ratio of angular momentum to magnetic moment is $2m/e$.

The theory given by Braunbek is essentially identical with that published in 1908 by O. W. Richardson [2] and used by J. Q. Stewart [3] in 1917 for the same purpose, when he obtained for iron and nickel results similar to those later obtained by Beck and by Arvidsson, to which Braunbek refers, and very recently by Chattock and Bates.[1]

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[1] Presented at the Los Angeles meeting of the American Association for the Advancement of Science, before the joint meeting at Pasadena of the American Physical Society with the American Astronomical Society, the Astronomical Society of the Pacific, and of Section D, September 18, 1923.

[2] O. W. Richardson, Phys. Rev., vol. 26, 1908 (24).

[3] J. Q. Stewart, Phys. Rev., vol. 11, 1918 (100).

The earliest successful experiments in this field were experiments on the magnetization of steel by rotation, of which the above-mentioned effect is the converse, made by L. J. H. Barnett and myself [2] and presented to the American Physical Society in 1914. They have been followed [3] by experiments of the same kind on soft iron, cobalt, nickel, cold-rolled steel, and Heusler alloys, for each one of which, on the assumption of a single type of magneton, such as the complex magneton of Richardson, with the axes of the rotating elements fixed in the atom, the ratio of the angular momentum to the magnetic moment has been found equal or nearly equal to m/e, the value found for steel in 1914, instead of $2m/e$.

Richardson's theory calculates the ratio of angular momentum to magnetic moment, which is the quantity (on the simplest hypothesis) sought in all these experiments. His formula fits the experimental facts when the rotation of the positive nucleus (or part thereof) is opposite to that of the negative electrons in motion, and when the magnetic moments, or the real velocities of the positive protons, are negligible. It is interesting to note that the nucleus cuts down the ratio of angular momentum to magnetic moment characteristic of the electron orbits, not by affecting the magnetic moment, but by decreasing the angular momentum, so that the rotation of neutral bodies in the nucleus, if that were possible, would suffice for the purpose.

While the negative-and-positive magneton hypothesis will account for the experimental results, it is also possible to account for them on the hypothesis that a single type of purely negative magneton is involved with a ratio of angular momentum to magnetic moment equal to m/e. In this connection we may observe that the Lorentz-Abraham uniformly and superficially charged electron in rotation about its axis has just this ratio m/e, as shown by Abraham [4] in 1903. Both hypotheses have advantages and both are difficult to reconcile with some of the facts.

Chief results of a preliminary analysis of the Earth's magnetic field for 1922. No. I: Zonal harmonics and uniform magnetic field. No. II: Non-potential system. Louis A. Bauer. Terr. Mag., vol. 28, 1–28 (March–June 1923).

Summary of results of a recent analysis of the Earth's magnetic field for 1922.[5] Louis A. Bauer.

Similarities in the magnetic fields of the Earth and the Sun. Louis A. Bauer. Pop. Astron., vol. 31, 186 (March 1923).

On the physical composition of the Earth's magnetic field in 1922. Louis A. Bauer. Phys. Rev., vol. 21, 370 (March 1923).

Some physical aspects of a recent analysis of the Earth's magnetic field.[6] Louis A. Bauer. Science, vol. 58, 113–115 (August 17, 1923).

The Earth's magnetic field for 1922. Louis A. Bauer. Nature, vol. 112, 295–298 (August 25, 1923).

These papers, of which the first mentioned is the principal one, present various aspects of the chief results of the author's preliminary analysis of the Earth's magnetic field for 1922, made as free as possible without assumptions as to the composing systems and restricted to the region of the Earth (86 per cent) from 60° N. to 60° S. Some of the chief results obtained will be found stated in the introductory remarks on the "Composition of the Earth's magnetic field" (see pp. 229–230).

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[1] Roy. Soc. Proc. A., Nov. 16, 1922 (see Nature, Nov. 25, 1922).

[2] S. J. Barnett, Phys. Rev., vol. 6, 1915 (239).

[3] S. J. Barnett, Phys. Rev., vol. 10, 1917 (7); S. J. Barnett and L. J. H. Barnett, Phys. Rev., vol. 17, 1921 (404, 405), and vol. 20, 1922 (90, 91). See also S. J. Barnett, Bull. Nat. Res. Council, vol. 3, 1922 (235).

[4] M. Abraham, Ann. Physik, vol. 10, 1903 (151, 159, 171).

[5] Presented at the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 18, 1923.

[6] Presented at the meeting of the American Philosophical Society, Philadelphia, April 21, 1923

Regarding measures of magnetic characterization of days. Louis A. Bauer. Terr. Mag., vol. 28, 41–44 (March–June 1923), and Bull. 3, Sect. Terr. Mag. and Electr., Internat. Geod. Geophys. Union, 115–117 (October 1923).

This paper continues the discussion and comparison of various measures of daily magnetic activity (see p. 292 of last year's report) looking toward the adoption of a measure which may fulfil more satisfactorily than the present "magnetic character numbers" the desiderata for such a measure. It appears best to continue the present scheme at all stations, meanwhile having a limited number of representative well-equipped stations compile, in addition, results at minimum time and labor which will serve to test out suggested measures.

On the organization and aims of the American Geophysical Union. Louis A. Bauer.

International and national work of the American Geophysical Union, July 1, 1922, to April 30, 1923. Louis A. Bauer.

These are reports on the administration of the Union, the first presented at the annual meeting of the American Geophysical Union, Washington, April 17, 1923, and the second at the annual meeting of the Division of Foreign Relations of the National Research Council, Washington, April 25, 1923.

The work of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. Louis A. Bauer.

This report, prepared for the Second Pan-Pacific Science Congress, held August 13 to September 3, 1923, at Sydney and Melbourne, Australia, gives an account of the organization and history of the Department of Terrestrial Magnetism. It also summarizes in detail, and with particular reference to the Pacific Ocean and adjoining continents, the work accomplished, including (1) ocean magnetic surveys by the *Galilee* and by the *Carnegie*, (2) land magnetic surveys in countries adjoining and on the islands of the Pacific Ocean, and (3) observatory work at the Watheroo and Huancayo magnetic observatories and, in cooperation with the New Zealand government, at the Apia Observatory.

Note regarding the annual variation of the atmospheric potential gradient. Louis A. Bauer. Science, vol. 58, 67–68 (July 27, 1923).

A brief discussion of an article in *Science* of May 25, 1923 (pp. 616–618), by Dr. Sanford, in which he attempts to account theoretically for the annual variation of the atmospheric potential gradient; his theory is shown not to be in accord with the chief observational results.

Earth-current observations. Louis A. Bauer. Science, vol. 56, 592–594 (November 24, 1922).

An abstract of the matter contained in this paper is given on pages 290 to 291 of the Director's annual report for 1922.

Solar activity and atmospheric electricity. Louis A. Bauer. Nature, vol. 112, 203–205 (August 11, 1923).

Dr. Chree, in a recent paper[1] giving the results of his investigation based on the Kew atmospheric-electric data, reaches the following interesting conclusion, as given in his statement: "The results obtained are on the whole not incompatible with Dr. Bauer's conclusion, but they indicate that if a relationship of the kind supposed exists, the sun-spot influence must be very much less in the case of atmospheric electricity than in that of terrestrial magnetism." The conclusion[1] referred to by Dr. Chree is that the potential gradient of atmospheric electricity apparently varies during the sun-spot cycle, increasing with increased sun-spot activity, and that the diurnal range of the potential gradient of atmospheric electricity, like the diurnal range of terrestrial magnetism, increases with increased sun-spot activity.

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[1] A supposed relationship between sun-spot frequency and the potential gradient of atmospheric electricity. Proc. Phys. Soc., London, vol. 35, part 3, 129–136 (April 15, 1923).

If there is a relationship between solar activity and atmospheric electricity, it ought to turn out to be a world-wide phenomenon, just as in the case of the recognized relationship between solar activity and terrestrial magnetism. This fact is to be kept in mind, that disturbances, because of local conditions, play a far more predominant rôle in atmospheric electricity than in terrestrial magnetism, and may in fact be of such a character as to mask completely any world-wide effect. Accordingly, in atmospheric electricity a very careful selection of stations is necessary for the study of world-wide phenomena.

After further discussion of the available data, the author concludes: The relationship between sun-spot activity and atmospheric electricity turns out to be, for locally undisturbed stations, as definite as in the case of terrestrial magnetism; the sun-spot influence on the periodic variations of the atmospheric potential gradient is, in general, as great as on the periodic variations of terrestrial magnetism; and as concerns the effects on the absolute values, the sun-spot influence is about 300 times greater in atmospheric electricity than in terrestrial magnetism. The potential gradient of atmospheric electricity, and, presumably, the Earth's total negative electric charge, is furthermore subject to an annual or secular change, which may vary in magnitude and sign from one sun-spot cycle to another.

Transactions of the Rome meeting, May 1922, of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union. Edited by Louis A. Bauer, Secretary and Director of Central Bureau. Bulletin No. 3, 182+viii pages, 3 plates (October 1923). Johns Hopkins Press, Baltimore.

This volume, containing the transactions of the Rome meeting in May 1922 of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union, constitutes Bulletin No. 3 of publications by that section. The volume is divided into three parts: Part I, statutes and organization; Part II, reports and communications at the Rome meeting under the subdivisions (*a*) status of magnetic surveys in 1922, (*b*) status of observatory work in 1922, (*c*) magnetic instruments and methods, (*d*) magnetic curves and characterization, (*e*) on questions of the agenda, and (*f*) communications on terrestrial electricity; and Part III, proceedings and minutes of the Rome meeting.

Earth-current observations by the Department of Terrestrial Magnetism. Louis A. Bauer. Bull. 3 Sect. Terr. Mag. and Electr., Internat. Geod. Geophys. Union, 153 (October 1923).

Report of the Chairman of Committee on Comparisons of Magnetic Instruments and Methods of Absolute Magnetic Measurements. Louis A. Bauer. Bull. 3, Sect. Terr. Mag. and Electr., Internat. Geod. Geophys. Union, 75–76 (October 1923).

Report of Secretary and Director of Central Magnetic Bureau, 1919–1922. Louis A. Bauer. Bull. 3, Sect. Terr. Mag. and Electr., Internat. Geod. Geophys. Union, 159–160 (October 1923).

On magnetic standards and comparisons of the Department of Terrestrial Magnetism. Louis A. Bauer and J. A. Fleming. Bull. 3, Sect. Terr. Mag. and Electr., Internat. Geod. Geophys. Union, 84–97 (October 1923).

This report includes the results of extensive comparisons of magnetic standards at observatories obtained during 1922 and the early part of 1923 by the Department. In its final form, it summarizes (1) the data and compilations leading to the definition of the provisional "International Magnetic Standards" adopted by the Department in 1914,[1] and (2) detailed information with tabular exhibits of pertinent data regarding the C. I. W. standard instruments, particularly the maintenance of "constants" and consistent behavior of the standard magnetometer used for horizontal intensity.

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[1] Terr. Mag., vol. 27, 30 (March–June 1922); see conclusion (*f*).

The confirmation of the provisionally adopted standard in intensity is indicated, within practical and theoretical requirements for such a standard, by the results of (1) intercomparisons with observatories, where requisite control of constants is maintained, for different series at widely separated times, (2) negligible weighted mean differences on absolute instruments of practically every type and design, constructed by makers throughout the world, at field stations and at observatories, and (3) small differences on apparatus using electromagnetic methods for absolute determinations of intensity, including (*a*) the C. I. W. sine galvanometer[2] of the Department of Terrestrial Magnetism of United States, (*b*) the Schuster-Smith magnetometer[3] of the National Physical Laboratory of England, and (*c*) the Watanabe electric magnetometer[4] of the Central Bureau of Weights and Measures of Japan (see pp. 256-258).

Tabulations summarize the results of (1) direct observatory comparisons and corrections on the provisional International Magnetic Standards obtained by the Department during 1905 to 1923 at 43 observatories in all parts of the world, and (2) indirect observatory comparisons and corrections on provisional International Magnetic Standards obtained through observations of other organizations at 18 observatories.

The accumulated data show that the provisional International Magnetic Standards adopted for the work of the Carnegie Institution of Washington are satisfactory and well within the magnitude of unavoidable errors of observation and of the determination of constants of the various types of instruments used. It also appears that the precision obtainable with carefully designed magnetometers and inductors, provided instruments are carefully used and comparisons are made with reliable standards at least every two or three years, is of the order 0′.2 in declination and inclination and less than 1/5,000 part of the observed value in horizontal intensity.

World magnetic survey. Louis A. Bauer and J. A. Fleming. Bull. 3, Sect. Terr. Mag. and Electr., Internat. Geod. Geophys. Union, 50-56 (October 1923).

Magnetic observatories of the Carnegie Institution of Washington. Louis A. Bauer and J. A. Fleming. Bull. 3, Sect. Terr. Mag. and Electr., Internat. Geod. Geophys. Union, 69-71 (October 1923).

Work in atmospheric electricity by the Department of Terrestrial Magnetism. Louis A. Bauer and J. A. Fleming. Bull. 3, Sect. Terr. Mag. and Electr., Internat. Geod. Geophys. Union, 149 (October 1923).

Comments on questions of the agenda. Louis A. Bauer and J. A. Fleming. Bull. 3, Sect. Terr. Mag. and Electr., Internat. Geod. Geophys. Union, 139-148 (October 1923).

The first three papers give the detailed accounts of the operations of the Department of Terrestrial Magnetism pertaining to terrestrial magnetism and electricity presented before the International Section of Terrestrial Magnetism and Electricity at the Rome meeting in May 1922. The fourth paper contains comments, based on the experience of the Department of Terrestrial Magnetism, with respect to questions and subjects of discussion according to the printed agenda, distributed before the meeting at Rome.

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[1] See Res. Dep. Terr. Mag., vol. II, 211-278 (1915); vol. IV, 395-475 (1921).

[2] S. J. Barnett, A sine galvanometer for determining in absolute measure the horizontal intensity of the Earth's magnetic field, Res. Dep. Terr. Mag., vol. IV, 373-394 (1921).

[3] A. Schuster, On a new method for determining the Earth's horizontal magnetic forces, Terr. Mag., vol. 19, 19-22 (1914). F. E. Smith, On an electro-magnetic method for the measrement of the horizontal intensity of the Earth's magnetic field., Phil. Trans. R. Soc London, A, vol. 223, 175-200 (1922).

[4] N. Watanabe, An electric magnetometer for traveling, Proc. Phys. Math. Soc. Japan, ser. 3, vol. 2, 210-223 (1920).

Proposed magnetic and allied observations during the total solar eclipse of September 10, 1923. Louis A. Bauer and J. A. Fleming. Terr. Mag., vol. 28, 29, 30 (March–June 1923).

Magnetic observations during the total solar eclipse. Louis A. Bauer and J. A. Fleming. Science, vol. 58, 62, 63 (July 27, 1923).

A proposed general program for field-station and observatory work, including magnetic, atmospheric-electric, and meteorological observations is outlined. The general circumstances of the eclipse are given and also a list of references giving detailed information with respect to meteorological and living conditions at places within the belt of totality.

On the physical interpretation of results of line integrals of the Earth's magnetic force.[1] Louis A. Bauer and W. J. Peters. Phys. Rev., vol. 21, 388 (March 1923).

At the Toronto meeting of the American Physical Society in 1921, the authors gave the results of line integrals of the Earth's magnetic force, taken around various complete circuits over ocean and land areas. The results were of such a magnitude and of such a character as not to be readily ascribable to observational errors.[2] In accordance with usual theory, the line-integral results would be regarded as indicating the existence of electric currents passing perpendicularly through the area inclosed by the circuit. The current density thus indicated would be about 10,000 times that shown by atmospheric-electric observations. The first author some years ago suggested another physical interpretation which has been reexamined in the light of the more recent data and on the basis of a new analysis of the Earth's magnetic field. It is found that the line-integral results reveal, in part at least, an effect similar to a deviation of the compass needle as though caused by forces set in operation during the Earth's rotation; the north end of the compass needle is found to be deflected along a parallel of latitude, on the average, between 5° north and 45° north about one-tenth of a degree toward the east, and for the corresponding region in the southern hemisphere about one-tenth of a degree towards the west (see also p. 266).

Formula for scale-value determination of declination variometers. H. M. W. Edmonds.

During April and May two formulæ that have been in use for determining the effective distance, R, between the movable mirror of the declination variometer and the recording drum of the magnetograph, were considered and tested experimentally. Lamont[3] corrected the measured distance for torsion and subtracted one-third the thickness of all intervening glass plates or lenses.

Kohlrausch[4] found that the effect of the variometer lens eliminates the distance between the lens and mirror. This led to the adoption of the formula

$$R=D+\frac{2m}{3}-\frac{l}{3}-\frac{c}{3}$$

where D = distance from back of lens to magnetogram; m = mirror thickness, and l and c = thickness of intervening lenses. A close study of Kohlrausch would seem to indicate the correct formula to be

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[1] Presented at the Boston meeting of the American Physical Society, December 28, 1922; a fuller publication will be made in the *Journal of Terrestrial Magnetism and Atmospheric Electricity.*

[2] See Phys. Rev., vol. 19, 427, 428 (April 1922).

[3] J. Lamont, Handbuch des Erdmagnetismus, Berlin, 1849 (90–96).

[4] F. Kohlrausch, Ueber die Correctionen bei einer Winkelmessung mit Spiegel und Scala, Ann. Physik u. Chemie, N. F., vol. 31, 1887 (95–100).

$$R=D-\frac{m}{3}-\frac{l}{3}-\frac{c}{3}$$

The experiments confirmed the correctness of the modified formula.

The Bermuda magnetic anomaly and possible effect on secular changes.[1] H. W. Fisk.

The peculiar interest in the local magnetic disturbances in Bermuda arises from the geological condition with which it is connected. The island is a submerged mountain of volcanic origin covered with a coral-limestone cap which, at the only point where a boring has been made, extends 250 feet below sea-level.

The author, under the auspices of the Department of Terrestrial Magnetism, made a magnetic survey of the island in 1907 and repeated a part of the work in the summer of 1922, carrying out at the same time some special investigations relating to local disturbances. In this later work, extensive tests were made which failed to discover any magnetic properties in the limestone, either in fragments or in large masses. The magnetic distribution, however, indicates that, besides the general disturbance affecting widely separated areas, there are others of local character that have their origin much nearer the surface. The compass-variometer, an instrument designed and constructed by the Department for the detection of small differences of horizontal intensity, was used to study a few limited areas in detail. In one such there were found differences of as much as 700 gammas (0.00700 c. g. s.) within less than 20 feet horizontal distance. There was no evidence of an artificial source for this disturbance. The soil at various points on the island was examined and found to be magnetic, though the distribution of these local disturbances could not be directly related to the depth or other apparent properties of the soil. There are, therefore, a major or primary source of disturbance lying deep in the lower structure of the submerged mountain, and other minor or secondary sources lying in or near the surface, probably in the soil.

Diurnal-variation observations with field instruments were made in declination simultaneously by two observers stationed at two points between which the differences in the magnetic elements were near the maximum amount. The simultaneous declination differences remained practically constant, and no evidence of any change in the diurnal variation either in range or phase due to the existence of the disturbance was found. A similar series of observations was made for the inclination, using earth inductors, obtaining a value every 15 or 20 minutes, and for horizontal intensity using the method of deflections at one distance repeated at similar intervals. For these elements good diurnal-variation curves were obtained, although, because of the magnitude of unavoidable errors of observation, they were not a satisfactory basis for any conclusions.

In the course of the work in 1907, five stations were chosen as repeat stations and carefully marked for reoccupation. Two of these were reoccupied in 1910 by the *Carnegie* party, and all were reoccupied in 1922. The small differences in the 15-year change in inclination and horizontal intensity at the different stations show a slight tendency to vary with the value of the element. When the results from the nearest magnetic observatories are available, by which an approximate reduction of observations at all stations to a common epoch may be made, it may be possible to determine whether this tendency is real. In the case of the declination, the evidence is positive. The two stations which were occupied in August 1907, in January 1910, and in August 1922 were found to have declinations which differed by 3° 53′, 3° 59′, and 4° 18′ on the three occasions respectively, showing a steady increase in the difference with time. This increase seems to be related in some way to the declination at the two stations and is suggested also by the results of the other stations; for if the 15-year change is plotted for each of the five stations, using the declination as abscissæ, the points fall near a line within limits on the order of the uncertainties of determination. It is hoped that a further refinement of intensity observations may make it possible to reveal a connection between this phenomenon and the components of the disturbance field.

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[1] Based on paper presented before the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 18, 1923.

Note on the determination of magnetic secular variation from ocean observations. H. W. Fisk.

Whenever it is permissible to assume (*a*) that a magnetic element varies uniformly or with a uniform acceleration along each meridian and along each parallel, (*b*) that the annual rate of change of the element at any point is constant or has a uniform acceleration, and (*c*) that the annual rate of change varies uniformly from point to point along each meridian and along each parallel, then the geographical distribution and the secular variation of that element may be expressed by an empirical formula of ten coefficients, consisting of a constant term, the first powers, squares, and second-power products of the differences between the position and epoch selected for reference and the latitude, longitude, and date considered.

While these three fundamental conditions apply strictly only to very small areas on the Earth's surface, they may be assumed to hold approximately for one or more of the magnetic elements over comparatively large areas in certain regions.

The section of the Atlantic Ocean lying immediately east of the United States and west of the meridian 45° west longitude has been traversed by the *Carnegie* on each outward voyage and return to home ports, so that observations are well distributed over this area, and have been made at various times between 1909 and 1921, thus presenting favorable conditions for testing results of adjustments by the foregoing formula. Such adjustments were made for all three magnetic elements in connection with the reduction and investigation of the Bermuda magnetic anomaly (see pp. 253–254).

The stations at which horizontal intensity and inclination were observed, 87 in number, were combined into 39 groups, so as to preserve as far as possible the maximum difference in time in each portion of the region covered and to make the groups of approximately the same weight. The resulting equations for declination and inclination give changes for two stations on the Bermuda Islands from 1910, when they were occupied by the *Carnegie* party, to 1922, when they were reoccupied by a land party, of -932γ in intensity and $+30'$ in inclination. The corresponding changes determined independently from the land observation are -944γ and $+33'$, an agreement well within the limits of determination.

The adjustment of the declination observations in the same area required a different grouping, as they were made at different times of day and were more numerous than those for intensity and inclination. In all, 129 stations were combined into 40 groups. Later, those groups lying north of parallel 32° N. and west of meridian 56° W. were adjusted separately, and finally an adjustment was made of the groups within one degree of parallel 38°, assuming the change along the meridians for the short distance involved to be that obtained from the earlier discussions. The residuals resulting from these adjustments were not satisfactory, the difficulty arising from the fact that the third of the three fundamental conditions is not fulfilled.

The foregoing method, when applicable, has the advantage of giving continuous curves representing the secular changes for all positions within the area investigated. The results obtained from track intersection, on the other hand, gives only the mean change at a single position over the time elapsed between the two passages, but has the great advantage of yielding a positive result, provided a suitable method is used to eliminate accidental errors, and to make the necessary interpolation to a common point.

The direct method of obtaining secular variation employed at land stations, namely, that of precise reoccupation of stations at intervals, has not been considered expedient in ocean work because of the delays that would ensue, and because of the necessarily large accidental error to be expected in any single observation. It has been customary, in deriving the preliminary values of annual change in previous discussions, to group observations in the vicinity of the intersection of two tracks, and from a mean suitably derived to interpolate a value of the element for the common point. The number of stations to be used in taking a direct mean is limited by the condition that the mean value must apply to the mean position, which can only be true when the change in the value of the element is a linear function of the distance between the stations; the determination of an acceleration factor by a least-square adjustment using the geographic coordinates is inexpedient because of the usual linear distribution of the stations. To supply an acceleration factor and thus reduce the probable accidental error at the intersection by using a greater number of observations, the following method was tried.

A portion of a cruise was selected over which the course approximated a great circle for a considerable distance, so that all stations were generally within a degree of a line computed from their geographic coordinates by use of the slope form of the equation of a straight line. The varying length of the longitude degree was compensated by multiplying that coordinate by the cosine of the latitude. The projected distance, d, of any station from the reference-point on such a line, and its perpendicular distance, p, from the line were readily computed from quantities previously derived. Since the stations were selected so that p was always small, the declinations were adjusted by use of a conditional equation,

$$\Delta D = h + xd + yp + zd^2 + wdp$$

involving only five coefficients.

Applications of this method promise improved values of secular changes at track intersections, and, while the computations are necessarily somewhat more extended than the more approximate methods previously used,[1] the improvement compensates the additional labor.

Latest annual values of the magnetic elements at observatories. J. A. Fleming. Terr. Mag., vol. 27, 157–160 (December 1922).

Data and distribution of magnetic observatories, 1922. J. A. Fleming. Bull. 3, Sect. Terr. Mag. and Electr., Internat. Geod. Geophys. Union, 72–74, 1 plate (Oct. 1923).

These papers give compilations of the most recent annual values of the magnetic elements at observatories distributed over the Earth. The second contains in addition information regarding publications and persons in charge; it has also a chart, prepared by C. C. Ennis, showing the distribution of magnetic observatories.

Comments on Weinberg's suggestions for field work. J. A. Fleming. Terr. Mag., vol. 27, 156, 168 (December 1922).

This paper is a brief discussion of a procedure proposed [2] by Professor Boris Weinberg in land magnetic-survey work. The field methods followed by the

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[1] See Res. Dep. Terr. Mag., vol. III, pp. 430–433

[2] Boris Weinberg, On the methodology of finding and representing the distribution of a natural element over a certain region of the Earth's surface, with special reference to terrestrial magnetism, Terr. Mag., vol. 27, 137–155 (December 1922).

Department of Terrestrial Magnetism of the Carnegie Institution of Washington to overcome some of the difficulties, especially in regions of local disturbance, referred to by Professor Weinberg, are given. The need of observations to determine the secular variation at frequent intervals is pointed out. Instrumental equipments and observational methods, particularly for stations in the higher magnetic latitudes, for relatively accurate determinations of the three elements within an hour or less are described.

Device for determining corrections because of shrinkage in photographic records. J. A. Fleming and C. Huff.

Uncertainty is sometimes introduced in photographic registrations because of unusual or unequal shrinkage of the sensitized paper used after the records are made and developed. For accurate scalings and reduction, correction on this account is by no means negligible, and, therefore, a standard shrinkage gage was designed for use at the observatories. The design provides for determination of corrections for changes in length as well as width, the latter being concerned with the quantity the variations of which are recorded; prevailing practice has been to take account only of shrinkage effects on measured ordinates. The increasing importance of the time element in investigations of recorded phenomena indicated the desirability of controlling possible shrinkage corrections and shrinkage variations in length of sheet also. It is found that shrinkage may vary under differing conditions of climate and storage, and, when rescalings are necessary, control of shrinkage must be made anew.

The device is so arranged that the sensitized paper, before being mounted on the recording drum of the registering apparatus, may be inserted and five lines of four fine holes pricked across the width of the sheet, the distance between the five lines being exactly 100 mm. The four holes marked in the width of the paper in each of the five lines are such that the distances between the first and the third and between the second and the fourth are also exactly 100 mm. The percentage of shrinkage to determine any correction necessary to measured ordinates or abscissæ may then be readily noted by measuring the distance between holes originally spaced 100 mm. for that part of the sheet concerned and the corrected scaling, without computation, taken from standard tables of corrected distances for measured percentage of shrinkage.

Comparisons of magnetic and electromagnetic methods for determining the horizontal intensity of the Earth's magnetic field. J. A. Fleming, H. W. Fisk, J. E. Ives, H. F. Johnston, and W. C. Parkinson.

This report gives the results of comparison observations made in 1921 and 1923 between the provisional International Magnetic Standard in horizontal intensity as adopted by the Department in 1914, depending upon observations with the standard C. I. W. magnetometer and that resulting from electromagnetic determinations using C. I. W. sine galvanometer No. 1 (see p. 243). The conditions for the comparisons were by no means good either in 1921 or in 1923, as moderate magnetic storms were in progress during part of each series. Because of the lack of precise calibration of the electrical constants for the electrical apparatus used with the sine galvanometer, the error in absolute standard by the latter may be as great as 1 in 7,000. The methods of observation and results are given in detail; the latter are summarized in table 1.

Additional field intercomparisons of magnetic and electromagnetic instruments for the determination of horizontal intensity of the Earth's magnetic field were made at Kakioka, Japan, in August 1922, and at the National Physical Laboratory at Teddington, England, in September 1922, with the Watanabe electric magnetometer and the Schuster-Smith magnetometer, respectively. The C. I. W. magnetometers used for these observations were compared both before and after field use with the standard instruments at Washington. Thus there is obtained indirectly a comparison between the

TABLE 1.—*Horizontal-intensity comparisons at Washington, 1921 and 1923, between provisionally adopted International Magnetic Standard and sine galvanometer.*

Series.	Date.	Hor. int. from—		I. M. S. minus S. G. I.	Weight.[a]	No. of sets.
		I. M. S.	S. G. I.			
	1921	γ	γ	γ		
A-I	June 3, 4	18686.9	18687.0	−0.1	1	$1\frac{3}{4}$
A-II	Aug. 2, 4	18683.4	18683.2	+0.2	3	$4\frac{1}{2}$
A-III	Aug. 5, 8	18665.0	18666.5	−1.5	4	6
A	Weighted means	18675.3	−0.7γ or −0.000 04*H*			
	1923					
B-I	Feb. 22, 23	18590.7	18593.0	−2.3	2	3
B-II	Feb. 23, 24	18601.4	18600.4	+1.0	[b]1	$3\frac{1}{2}$
B-III	Feb. 25, 26	18577.4	18580.2	−2.8	2	4
B-IV	Mar. 2	18588.0	18589.8	−1.8	1	$2\frac{1}{2}$
B	Weighted means	18587.6	18589.4	−1.8γ or −0.00010*H*		
Resulting value (I. M. S.—S. G. 1) from A and B				−0.00007*H*		

[a] The weights are assigned according to the number of sets, number of days on which observations were made, and magnetic conditions.

[b] The small weight assigned is because the station-difference involved depends upon exchange of magnetometers only.

TABLE 2.—*Summary of horizontal-intensity comparisons between provisional International Magnetic Standard of Carnegie Institution of Washington and electric magnetometers, August 1922 to March 1923.*[a]

Standard or instrument.		Horizontal-intensity correction, $\frac{\Delta H}{H}$, on—			
Description.	Designation.	IMS.	SG.	SS.	W.
Provisional International Magnetic Standard of Carnegie Institution of Washington.[b]	IMS	....	+0.00007	[c] +0.00015	+0.00040
Sine galvanometer No. 1 of Carnegie Institution of Washington	SG	−0.00007	....	[c] + .00008	+ .00033
Schuster-Smith magnetometer of National Physical Laboratory	SS	[c] − .00015	[c] − .00008	....	[c] + .00025
Watanabe electric magnetometer No. 1	W	− .00040	− .00033	[c] − .00025	....

[a] The table is to be read thus, for example, first row:

$SG-IMS=+0.00007H$; $SS-IMS=+0.00015H$; $W-IMS=+0.00040H$.

[b] This provisional standard was adopted in 1914 (see Res. Dept. Terr. Mag., vol. II, 270–279 (1915).

[c] This value is subject to correction for any station-difference which may be found between the two observing piers used at Teddington, England, for the comparisons in September 1922.

three electric instruments and the provisional International Magnetic Standard of the Carnegie Institution of Washington. Table 2 summarizes the results.

General description of the earth-current measuring system at the Watheroo Magnetic Observatory. O. H. Gish. Terr. Mag., vol. 28, 89–108 (September 1923).

This paper consists essentially of two parts, the first being an analysis setting forth the general requirements for the determination of the earth-current density vector, and the second a description of the outstanding features of the system installed at the Watheroo Magnetic Observatory (in Western Australia) for measuring the potential gradient of earth currents.

General requirements.—A complete description of earth currents requires a knowledge of the distribution of (1) the earth resistivity, and (2) the earth-current potential. A method suitable for determining the former is indicated. The major portion of the analysis, however, deals with the potential gradient. It is first indicated that a "potential survey" should be made in the vicinity of earth-current lines in order to locate and measure any discontinuities that may exist in the potential field. General methods of approximately determining the potential gradient at a point are then given. The relations for resolving and combining earth-current potential measurements are developed in such a manner as to include the less favorable cases where the lines are not at right angles to each other.

The *earth-current lines at Watheroo* are so arranged that the earthed points determine a right angle, one limb of which extends due east and the other due north from the vertex. The point at the vertex is used as a common point of reference for the potentials of the other points. Two other points on each limb are situated, at present, 1.6 km. and 3.2 km. distant, respectively, from the common point. The potential difference between the common point and the nearer point on each branch can be alternately recorded by means of overhead and underground lines, and thus a close comparison of the relative virtue of these two types may be made. Only overhead lines connect with the farther point on each branch. The overhead lines possess no features of special interest. The underground lines consist of leaded rubber-covered copper conductors in bituminized fiber conduit, placed at a depth of 46 cm. below the earth's surface. The recorder is a modified Leeds and Northrup 12-point curve-printing potentiometer. For other details, reference may be made to the complete article.

A simple quantitative determination of the contact resistance of individual earthed electrodes. O. H. Gish.

Although obviously capable of wider application, the method here outlined was developed in connection with earth-current investigations and is discussed from that point of view. The electric-circuit resistance in a single arm of an earth-current measuring system consists of (1) the resistance of the metallic line, (2) that of the measuring instruments, (3) the contact resistance of the electrodes, and (4) the earth resistance.

The contact resistance of the electrodes (3) is usually of a higher order of magnitude than that of the earth (4) and is to some extent capable of control. It depends principally upon the effective contact surface of the electrode and on the resistivity of the soil lying within a radius of 3 to 6 meters about the electrode; it is not simply related to the actual surface of the electrode, but depends on the physico-chemical condition of the electrode surface, as well as on that of the soil, and even more upon the extension of the electrode in the earth.

When installing earth-current lines it may be desired to increase the extension of an electrode in order to decrease its contact resistance (and thus the total circuit resistance) to an order of magnitude determined by the measuring instruments employed. This may be done systematically if the individual contact resistances are known.

With the circuit resistance thus adjusted, the contact resistance has further interest in so far as its variation indicates such physico-chemical changes in the vicinity of the electrodes as would bring with them changes in the contact potentials, and consequently false indications on the records. Thus, in addition to insuring more suitable resistances when the electrodes are being installed, this method will, it is believed, also furnish information helpful in dealing with the troublesome spurious potentials which from time to time arise at the electrodes.

The essential to the method is to have two electrodes in the vicinity of each terminal of the line (one of each pair may be only temporary), so arranged that they may be connected to the line singly or in pairs. Then if x and v are the contact resistance of two electrodes at one end, and R_1 the resistance measured when x alone of the pair is in circuit, R_2 that when x and v are both connected, and R_3 that when v alone is connected, then:

$$x=R_2-R_3+\sqrt{(R_2-R_1)\ (R_2-R_3)}.$$

The other resistances may be determined in a similar manner, from two additional measurements.

A technique for preparing the moving elements for string electrometers and Einthoven galvanometers. O. H. Gish.

The quartz fibers which are used for string-electrometer elements are made by (*a*) "blowing out" quartz glass in an oxyhydrogen blast (see pp. 260–261). They then (*b*) receive a coat of gold by the "electric spray" or "sputtering" method, after which they are (*c*) tested for resistance, and fibers of the desired resistance and size selected (*d*) to mount into a transferable element.

The present report has little new to add under (*a*) and (*b*), except that "kinks" may be removed from raw fibers by passing them through a low Bunsen flame and that considerable time may be saved by "sputtering" 12 to 15 fibers at a time instead of 1 or 2, as has been done heretofore. The latter is done by mounting the fibers on a small glass frame which is about 0.5 inch wide and 6 inches long, and which, when filled with fibers, has the appearance of a miniature harp.

The operations under (*c*) immediately precede the mounting of fibers into electrometer elements. The first of these is to select a fiber (or in case of the bifilar elements, two fibers) of the desired diameter, using for this purpose a compound microscope of about 400 diameters magnification. The fiber is then removed from the frame with a special tool which resembles a pair of dividers. The chance of breaking fibers has been greatly lessened by providing this with flexible points made from strips of phosphor-bronze sheet about 0.08 mm. thick. Fused shellac is used for attaching the fiber. It is then brought into contact with two thin silver wires which extend so as to form a pair of very flexible and parallel cantilevers about 10 cm. apart, and the resistance measured with a Wheatstone bridge. The average resistance, which of course varies with a number of factors, is about 300 ohms per centimeter length of fiber.

In all mounting operations (*d*) where unmounted fibers are to be transferred, a universal-motion device having both rough and fine adjustment is helpful. Three such units are needed for the device to assemble the element for a bifilar (Wulf) electrometer. Such a "mounting device" was designed and constructed. With it much of the uncertainty in the mounting of fibers has been eliminated, the quality has been improved, and the nervous strain on the manipulator greatly reduced.

A conducting cement for attaching the fiber to the upper supporting lug has been made. This is more convenient to apply than low-melting-point solder and, as a number of tests show, is in other respects equally good. It consists of shellac dissolved in alcohol and made conducting by the addition of fine powdered graphite.

Before finally attaching the two fibers of a bifilar element, the tension is adjusted until the displacements of the fibers, which result when a small electric heater is suddenly brought to a position about 10 cm. below them, are equal. The frames of gilded fibers and also the mounted fibers when stored in a dust-free place in the laboratory may apparently be kept without appreciable deterioration for a number of years.

Making an automatic focusing enlarger. C. A. Kotterman. Photo-Miniature, vol. 16, 405–451 (May 1923).

The paper describes an enlarger by which focusing for different-sized images is accomplished by a cam mechanism which automatically adjusts the positions of the lens and negative with respect to the easel; thus the enlarged image is made to grow or shrink in size with perfectly sharp focus maintained, regardless of the degree of enlargement with the elimination of the trial and error defect.

Among the novel features of this apparatus is the employment of the miniature-camera lens as the enlarging lens and the convertibility of the device. In one form it is a self-contained oufit producing maximum enlargements of 8 by 10 inches from negatives or portions of negatives 2.25 by 3.25 inches and smaller. When used this way the outfit is operated very much like a camera and requires no dark room. By means of a very simple adjustment the self-contained form is readily converted into a modern projection printer with a capacity of 8 degrees of magnification with the automatic feature retained.

Numerous photographs of the device as built by the author show the various parts of the outfit in assembled and unassembled form; attention is called to the importance of conjugate foci and the part played thereby in automatic enlarging; the necessity of knowing the exact equivalent focus of the enlarging lens is emphasized; each part of the apparatus is then described in detail, so that a duplicate may be constructed quite readily from the information given.

The monograph concludes with a short note on the design and construction of special cams, with working formulæ which may be followed in developing a cam of proper size for a lens of any focal length.

Notes on the production of quartz fibers. C. A. Kotterman.

Quartz fibers in one form or another are frequently required for suspensions of moving parts of apparatus, yet the articles by Boys[1] and text-book references[2] give but meager information on methods for making such fibers. The production of fibers of uniform diameter over considerable length and of diameters 0.002 to 0.010 mm., suitable for use in electrometers, galvanometers, and other delicate instruments, is a simple matter, but difficult for most laboratory workers because of the lack of knowledge concerning the correct procedure to follow. Accordingly, some experiments were made regarding the suitable apparatus and methods for obtaining such fibers by the cross-bow method. Fibers of a diameter less than 0.002 mm. are more readily obtained by the flame method as described in detail by Coblenz.[1]

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[1] See Vernon Boys's "On the production, properties, and some suggested uses of the finest threads," Phil. Mag., June 1887 (also printed in Jour. Soc. Arts, 1889), and "The attachment of quartz fibers," Phil. Mag., vol. 37 (1894).

[2] William Watson, "A text-book of practical physics," Longman, Green & Co. (581–586).

Following the general method due to Boys,[2] various kinds of woods were tried out for bows. Bows were made up in different cross-sections and lengths; an improved type of trigger release and bow holder was evolved, and materials for arrows were investigated. Ash, lancewood, greenheart, and long-leaf pine were tried for bows, while soda straws, wheat straws, and slivers of wood were tried for arrows.

A satisfactory target was constructed of two squares of corrugated cardboard with an air-space of 1 inch between them and hung about 3 inches from a vertical wall. It was found that the arrows would embed themselves about half their length in the two pieces of corrugated board without in any way damaging the arrows.

The collecting of fibers after shooting was facilitated considerably by the use of four light wooden stands about 3.5 to 4 feet high, carrying lengths of glass tubing parallel to the floor. They were placed so as to divide the space of 30 feet between the bow and the target into five equal parts. The fibers shot were found to rest on the row of parallel glass rods, and it then became an easy matter to mount them on small wooden frames or otherwise store them. The diameters of the fibers are readily measured with a high-power microscope equipped with graduated eye-piece.

A most useful accessory for fiber work was a small electric heater operating from a storage battery or small alternating-current transformer. It consisted of a Cutler-Hammer 70–50 switch into one end of which was set a short length of bakelite rod. Two brass wires were set into grooves in the bakelite rod and a loop of resistance wire mounted in the outer ends. This loop was bent in the form of a small hairpin and glowed to redness when the proper current was sent through the loop. The Cutler-Hammer switch enabled the heater to be turned on and off by the hand holding it. This heater was found convenient not only for attaching short lengths of fibers to suspension hooks and for dropping bits of molten shellac as little anchors on to the fibers when collecting and storing them, but also proved its usefulness in many other ways.

The fineness of a quartz fiber obtained by the cross-bow method depends to some extent upon the elastic properties of the bow and the velocity with which the bow returns to its position of equilibrium after the trigger is released, but mainly upon the size of the piece of quartz fused. Slivers of clear quartz about one thirty-second inch or 0.5 mm. in diameter, heated to a dazzling whiteness in an oxyhydrogen flame, for about one-eighth inch of the sliver, gave the finest fibers. Fibers made from cloudy quartz rod or from quartz heated in an oxyacetylene flame proved unsatisfactory. With a bow of given elasticity and an arrow of minimum mass, the smaller and hotter the bit of quartz heated, the finer the fiber drawn out. From hundreds of shots made with this apparatus, it is concluded that the secret of obtaining long, fine quartz fibers of uniform cross-section resides in the amount of quartz heated and the temperature to which it is raised.

Report on determination of geographic positions and magnetic elements at Maya ruins, Peten, Guatemala, 1923. W. A. Love.

The Department cooperated with the party sent out by Dr. S. G. Morley, Associate of the Institution in Middle-American Archæology, under the leadership of Mr. O. G. Ricketson, to obtain the geographic positions of the Maya ruins visited during March and April 1923. The requirements set were (*a*) that values for latitude and for longitude be correct within one-half mile, and (*b*), because of the difficult transportation conditions to be encountered through dense tropical vegetation and short time available, that only the most portable instrumental outfits be carried.

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[1] See "Investigation of infra-red spectra," by William W. Coblentz, Carnegie Inst. Wash. Pub. No. 65, 126–127 (1906).

[2] See R. Threlfall's "On laboratory arts," Macmillan & Co., 1898 (196–226), and "On the elastic constants of quartz threads," Phil. Mag. (July 1890).

A theodolite-magnetometer with 101-mm. vertical and horizontal circles of Department design and construction[1] was used for the astronomical and magnetic observations. Latitudes were determined from circummeridian observations of the Sun and local mean times by morning and afternoon observations of the Sun at as nearly equal altitudes as the time and conditions at the stations permitted. (For detailed description of the methods of observation and reduction followed, see pp. 22–33 of volume I of the Researches of the Department of Terrestrial Magnetism.) For determining the corrections on standard time for the chronometers a long-wave wireless receiving-set of the United States standard destroyer type was used with slight modification necessary for its operation with dry-cell batteries. This set consisted of receiver with load-coil to increase the receiving range (the range of wave-lengths being 600 to 25,000 meters), audion control-panel with one vacuum-tube, and an amplifier with two vacuum-tubes. The tubes were Western Electric type N, and the same ones were used throughout the field work. The set-up of antenna, phosphor-bronze stranded cable, was varied to suit circumstances, trees serving usually as supports. The length was generally 200 feet, but frequently less, and for one set-up it was only 50 feet; the height averaged about 50 feet. This equipment functioned excellently, and all longitude determinations except for one station depend upon time-signals received from either the Balboa or Arlington station, or both, before and after local time observations. Trouble was experienced frequently with static, but the signals were distinguishable despite this.

That the desired accuracy for both latitude and longitude was obtained is indicated by the plane-table traverse carried out by Mr. J. O. Kilmartin, junior topographic engineer of the United States Geological Survey, between Tayasal and Ixlu, in mapping Lake Peten. The agreement between plane-table positions and those determined as above indicated was within about one-quarter minute of arc.

Observations for the magnetic elements were made when opportunity offered. Examinations made, so far as the limited time available at each station permitted, indicated that there had been no attempt to follow any definite orientation when constructing the pyramids. El Cayo, British Honduras, served as the base-station, and therefore the results obtained there are included. (For details as to methods followed, see volumes I, II, and IV of "Researches of the Department of Terrestrial Magnetism.")

On the diurnal variation of the potential gradient of atmospheric electricity.[2] S. J. Mauchly. Terr. Mag., vol. 28, 61–81 (September 1923).

Further results on the diurnal variation of the potential gradient of atmospheric electricity from observations aboard the *Carnegie*, and comparisons between land and ocean results.[3] S. J. Mauchly. Phys. Rev., vol. 21, 721–722 (June 1923).

New observations obtained aboard the *Carnegie* during the year ending November 1921 increased by 50 per cent the observational data regarding the diurnal variation of the potential gradient over the oceans. A separate analysis of the new data has confirmed the results announced by the author in 1921[1] regarding the predominance, over the oceans, of a 24-hour wave progressing approximately according to universal rather than local time. It is found, however, that, at least in the Pacific, there is also a well-defined secondary wave during the months of northern summer.

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[1] J. A. Fleming, Two new types of magnetometers made by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, Terr. Mag., vol. 16, 1–12 (March 1911).

[2] Presented before the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 18, 1923.

[3] Presented before the American Physical Society, Washington, April 20, 1923.

The present investigation has been extended to include also the diurnal variation of the potential gradient over the several continental areas. From harmonic analyses of the diurnal variation from many widely separated stations, varying in latitude from 78° north to 77° south, it is found that, despite the greater complexity of the variation over land, a large percentage of the stations considered show sufficiently good agreement with the ocean results to furnish strong evidence for the assumption of *a world-wide effect of 24-hour period progressing approximately according to universal time.* The average amplitude of this wave is about 20 per cent of the mean-of-day value and the average time of its greatest phase apparently varies somewhat with time of year, ranging from about 16^h to 19^h G. M. T.

While there are land stations in the tropical and temperate regions for which the analytical results are not in accord with the foregoing, there is considerable evidence indicating that this may be due to local disturbances of large amplitude rather than to an absence of the general phenomenon. The fact that for φ_2, the phase angle of the 12-hour wave at local midnight, marked departures from the all-stations mean are largely confined to places where the amplitude of the secondary wave is relatively small lends further support to the view that the limitations of harmonic analyses in the form here used may be partly responsible for the lack of more complete agreement between the land and ocean results.

Observatory equipment for recording photographically the electric conductivity of the air.[2] S. J. Mauchly.

An abstract of the matter contained in this paper is given on pp. 303–304 of the Director's annual report for 1922.

The potential gradient at the Apia Observatory, Samoa, for the year ending April 30, 1923: Preliminary results. S. J. Mauchly.

The potential-gradient registrations at the Apia Observatory, together with the required control observations, were carried out during the period in question by Mr. Andrew Thomson, of the Department of Terrestrial Magnetism. On account of the deterioration of the old instrument hut, a new one was constructed under Mr. Thomson's direction in March 1922, due care being taken to introduce no material changes in the location of the hut and the exposure of the collector. The same ionium collector and Benndorf electrometer are used as in recent years at Apia, although the instrument was thoroughly overhauled and put in good condition before the present series of observations was begun.

The following preliminary results are based upon 112 selected days. *No negative hourly values are included*, although a few hours containing short periods of negative potential have been used in order to have a reasonable number of days for the formation of diurnal-variation curves for each quarter of the year. In accordance with the usual assumptions these curves have been subjected to Fourier analysis; the results are summarized in table 4, where the phase angles (φ) refer to local midnight and the amplitudes (c) are expressed as percentage of P_m, the mean-of-day value.

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[1] Bulletin of the National Research Council, No. 17, pp. 73–77, Washington (1922), and American Physical Review, n. s., vol. 18, pp. 161–162 and 477, August and December 1921.

[2] Presented before the annual meeting of the section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 18, 1923.

Table 3.—*Summary of results of preliminary analysis of the diurnal variation of the potential gradient at the Apia Observatory for year May 1922 to April 1923, inclusive.*

Months.	N	Pm	φ_1	φ_2	φ_3	φ_4	φ_5	c_1	c_2	c_3	c_4	c_5	c_2/c_1
	days	*V/m*	°	°	°	°	°	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	
May, June, July....	33	97	239	200	8	10	154	20	22	12	8	8	1.12
Aug, Sept, Oct.....	34	110	275	202	31	−13	230	15	24	3	11	2	1.61
Nov, Dec, Jan......	21	111	299	217	71	1	217	8	26	5	15	1	3.33
Feb, Mar, Apr......	24	101	277	209	15	− 8	162	20	29	10	16	7	1.43
Arithmetic means..	28	105	272	208	31	− 2 (358)	191	16	25	8	12	4	1.87

The following features of table deserve brief mention thus:

(*a*) The constancy, throughout the year, of φ_2 and φ_4, for which the ranges, expressed in time, amount to only 0.6 hour and 0.4 hour, respectively.

(*b*) Except during the May-July quarter, the amplitude of the fourth harmonic, c_4, is consistently greater than c_3.

(*c*) Rather large differences, corresponding to 4 to 6 hours, are found, between the Apia values of φ_1 and those obtained for the corresponding times of year from the observations made in the Pacific Ocean, aboard the *Carnegie*. But these apparent differences may possibly be due, at least in part, to the rather large local effects indicated by the analysis.

(*d*) The annual variation of the potential gradient for the 12 months in question appears to have been very small; in fact, the variation here shown may practically disappear, or even be reversed, when the effect of the removal of a tree in November 1922 from the vicinity of the recording hut has been fully determined.

Comparison of the above results with those previously obtained at Apia must await the accumulation of data for a period of time more nearly comparable with the length of some of the earlier series. It is hoped also that registrations of the potential gradient now being obtained at an observatory erected on a reef at some distance from the island (see p. 242) may furnish valuable data for the solution of some of the problems of atmospheric electricity as evidenced at Apia.

The diurnal variation of atmospheric-electric conductivity and air-earth current from observations obtained on the *Carnegie*. S. J. Mauchly.

During the months April to October 1921, fourteen 24-hour series of simultaneous diurnal-variation observations for positive and negative conductivity, λ_+ and λ_-, and potential gradient were obtained by Messrs. J. P. Ault and A. Thomson on the *Carnegie*. The extreme latitudes represented by these observations were about 29° south and 34° north, and, with the exception of one series in the Caribbean Sea, all were obtained in the Pacific Ocean. Half the observations were made within 15° of the equator, average latitude 8°, and the remainder near the tropics, with an average latitude of 26°.

As found for λ_+ from earlier observations on the *Carnegie* (see p. 356 of the 1921 report), the diurnal variation for both λ_+ and λ_- is less pronounced than that of the potential gradient and progresses according to local time. Separate mean curves representing the region of the tropics and of the equator, however, indicate some interesting differences. Although both curves show maxima in the neighborhood of 8 to 10 a. m. and 8 to 10 p. m., the intervening minimum appears from these observations to be decidedly secondary for the region of the tropics, while it is the principal minimum for the region of the equator. The mean values, expressed in unit of 10^{-4} E. S. U., are as follows: For the region of the tropics, $\lambda_+=1.65$ and $\lambda_-=1.44$, and for the region of the equator, $\lambda_+=1.63$ and $\lambda_-=1.38$.

The diurnal variation of the vertical air-earth current, as computed from the potential gradient and total conductivity, resembles very closely that of the potential gradient as regards its main features. That is, the curves from widely separated regions show very much greater similarity when referred to the same time basis than when referred to their respective local times. This, too, is in agreement with the 1921 results, which, however, referred to the positive current alone (see reference above). The mean value of the current density from these observations is about 9×10^{-7} E. S. U. (3×10^{-16} ampere per square centimeter), and the range of the mean diurnal variation is about 30 per cent of this value.

On earth currents and polar lights. S. J. Mauchly. Bull. 3, Sect. Terr. Terr. Mag. and Electr., Internat. Geod. Geophys. Union, 152 (September 1923).

This is a brief report dealing with plans for stimulating interest in, and increasing the number of reliable observations for, earth-current and polar-light investigations, and is based upon a progress report submitted in 1922 to the American Geophysical Union (see pp. 305, 306 of last year's report).

The results of potential-gradient registrations at Washington, District of Columbia, for the years 1917 to 1922. S. J. Mauchly.

In the last annual report (pp. 304, 305) preliminary results were given regarding the diurnal and annual variations of the potential gradient at Washington for the year 1918. As then stated, these registrations were obtained on the deck of the laboratory of the Department of Terrestrial Magnetism, in an observatory maintained primarily for experimental and instructional purposes.

The reduction of the records for the 6-year period 1917–1922 has now been completed and sufficient progress has been made in the analysis of the data to show that the preliminary results given for 1918 (*l. c.*) hold also for the entire 6-year period. This is especially true as regards the characteristics of the diurnal variation; however, as might be expected, the positions of the maximum and minimum of the annual variation sometimes occur a month earlier or later than those found for 1918.

The removal in 1920 of a hill covered with trees, near the observatory, introduced a discontinuity into the series so far as yearly change is concerned, the nature of the effect being, as would be expected, to cause an increase in the recorded potentials. Thus, the reduction factors determined during 1922 and 1923 are not applicable for the period prior to 1920. However, of the mean recorded values corresponding to the years 1917 to 1919, inclusive, those for 1918 were the largest, and all data obtained since 1919 show a diminution in the successive annual values ranging from 3 to 5 per cent per year. The annual values, in volts per meter, for the years 1920 to 1922 are 186, 181, and 174, respectively. The annual values of the recorded potentials for 1917 to 1919 are 151, 158, and 146 volts, respectively.

Harmonic analysis of the data shows a larger amplitude for the 24-hour wave than for the 12-hour wave, except in the summer months. It is also found that with the exception of the summer months, the time at which the 24-hour wave reaches its maximum, is in general accord with the results obtained from the ocean observations on the *Carnegie* (see pp. 262–263). The mean phase angle of the 12-hour wave at local midnight varies with the time of year and is of the order of 160° to 190°.

Magnetic east-west paths around the earth. W. J. Peters. Terr. Mag., vol. 28, 83–88 (September 1923).

In the Preliminary Analysis of the Earth's Magnetic Field for 1922[1] it was found desirable to ascertain how an east-west path around the Earth would close that was everywhere throughout its length perpendicular to the direction of the compass-needle, or to the horizontal component of the Earth's magnetic field. The considerations involved and the method adopted in ucting such paths are given.

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[1] Chief results of a preliminary analysis of the Earth's magnetic field for 1922, Louis A. Bauer. Terr. Mag., vol. 28, pp. 27, 28 (March–June 1923).

Results were obtained for eleven paths, based mostly on the data of British Admiralty Charts Nos. 3775, 3776, and 3777, and partly on Chart No. 2598, all for the epoch 1922. The paths all begin on the meridian of Greenwich and extend eastward from the following latitudes: 50°, 40°, 30°, 20°, and 10° north, the equator, 10°, 20°, 30°, 40°, and 50° south. The path that begins at the equator lies partly north and partly south of the equator. Accordingly, it has been omitted in deriving the different means. The mean lack of closure for the northern paths is 21.2 statute miles southward of the starting-points, while for the southern paths the mean is 59.6 statute miles northward. These distances correspond to an average deviation of the compass-needle, in the northern hemisphere equal to 3′ east and in the southern hemisphere 9′ west of north.

Equipment, installations, and work of Watheroo Magnetic Observatory.[1] G. R. Wait.

This paper gives a general account of the location, site, and buildings of the Watheroo Magnetic Observatory, with particulars as to the instrumental equipment and present and contemplated schedule of observations and personnel. Continuous registrations of the three magnetic elements (declination, horizontal intensity, and vertical intensity), of both positive and negative electrical conductivity of the air, and of earth-currents on underground and aerial lines, are being obtained, together with the necessary control observational data for the interpretation of the magnetograms and electrograms. A full program of meteorological observations is being carried out also, more particularly for the investigation of any relations to the atmospheric-electric work. Apparatus for recording the potential gradient of the atmosphere is to be installed soon. It is hoped to add seismographs also.

The attempt is made to keep the tabulation of data as nearly current as possible, thus permitting compilation and publication of results at the main office of the Department of Terrestrial Magnetism in Washington. Reports regarding magnetic storms, atmospheric-electric and earth-current disturbances, magnetic character of days, earthquake records on magnetograms, and other matters of current interest, are regularly communicated to interested organizations and through the *Journal of Terrestrial Magnetism and Atmospheric Electricity*. The meteorological results are supplied regularly to the Commonwealth Weather Bureau of Western Australia.

The successful initiation and realization of the observatory's scientific work was made possible through the cordial and interested cooperation of the Government officials and of the scientific men of Western Australia.

Earthquake records, Watheroo magnetograms, November 1921. G. R. Wait. Terr. Mag., vol. 27, 167 (December 1922).

Magnetic and atmospheric-electric disturbances and auroral displays, Western Australia, January 1923. G. R. Wait. Terr. Mag., vol. 28, 49 (March–June 1923).

These articles give brief accounts of earthquake effects and of magnetic and atmospheric-electric disturbances recorded at Watheroo Magnetic Observatory, Western Australia, together with notes from various sources regarding auroral displays noted at several places in Western Australia.

Earthquake records, Huancayo magnetograms, October to November 1922. W. F. Wallis. Terr. Mag., vol. 27, 167 (December 1922).

Earthquake records, Huancayo magnetograms, September 1922 to April 1923. W. F. Wallis. Terr Mag., vol. 28, 48, 49 (March–June 1923).

These articles give brief accounts of the earthquake and the magnetic phenomena indicated as recorded on the magnetograms obtained at the Huancayo Magnetic Observatory, Peru.

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[1] Presented before the Second Pan-Pacific Science Congress held during August 13 to September 3, 1923, at Sydney and Melbourne, Australia.

ARCHÆOLOGY.

Morley, Sylvanus G., Santa Fe, New Mexico. *Associate in Middle American Archæological Research.* (For previous reports see Year Books Nos. 13–21.)

Three separate and independent expeditions were maintained in the field during the season of 1923, as follows: Dr. Morley in Mexico, Yucatan, Guatemala, and Honduras; Messrs. Ricketson and Love (Department of Terrestrial Magnetism, Carnegie Institution of Washington) in northeastern Peten, Guatemala; and Mr. Kilmartin (United States Geological Survey) at Tayasal on Lake Peten, Guatemala.

The activities in Middle American Archæological Research for the current year may be described under five main headings, as follows:

1. The securing of permits from the Governments of Guatemala and Mexico for the inauguration of intensive excavation projects in these respective countries, to extend over a period of years, by Dr. Morley.
2. The discovery of new hieroglyphic inscriptions from Chichen Itzá, Ocosingo, Chiapa, Copan, and in the National Museum of Archæology and History at Mexico City, by Dr. Morley.
3. The determination of the exact geographical positions by latitude and longitude of 12 of the most important archæological sites in northeastern Peten, by Messrs. Love and Ricketson, being the seventh season of work in this region.
4. A topographical survey of Lake Peten, Guatemala, with special reference to the location and topographical characteristics of the ancient Itzá capital of Tayasal, by Mr. Kilmartin, being the third season of work at this site.
5. The preparation of the report on the archæological sites along the east coast of Yucatan, with special reference to the ruins of Tuluum, by Dr. Lothrop, now in press (Publication No. 335).

Dr. Morley left Washington on January 31, for Yucatan, to make arrangements for the visit of the President of the Institution and General Parsons of the Board of Trustees, who followed a week later. The purpose of this trip was, by a first-hand examination of the ruins of Chichen Itzá, to ascertain the nature of the archæological problem at this site and how far the Institution might cooperate in its solution.

The President and General Parsons returned to the United States after a fortnight's stay in Yucatan; and Dr. Morley, after a further examination of Chichen Itzá, left Yucatan on March 30 for Mexico City, to lay before the Direction of Anthropology of the Ministry of Agriculture and Public Works, in preliminary and unofficial conversations, the outline of a plan for archæological investigations at Chichen Itzá by the Institution.

On April 16 Dr. Morley proceeded to Guatemala City, where he took up with Señor Don Abraham Cabrera, the Minister of Public Instruction, the question of securing a permit from the Government of Guatemala, under which excavations and archæological studies might be carried on at any one or all of the three following sites: Uaxactun, Piedras Negras, and Tayasal, in the Department of Peten.

The permit obtained concedes, for a period of five years beginning January 1, 1924, the privilege of making excavations and archæological studies at these sites, under the direct supervision of the Minister of Public Instruction. It was signed by that official on behalf of the Government of Guatemala on May 12 and delivered to Dr. Morley on May 23.

On the occasion of the formal organization of the Geological and Historical Society of Guatemala, Dr. Morley delivered an illustrated lecture, on the archæological remains of the Republic, in the *Palacio Centenario* in the presence of President Orellana, the cabinet, and diplomatic corps. He returned to Mexico on May 26.

The President of the Carnegie Institution arrived in Mexico City on June 2, and at once began conferences with Dr. Manuel Gamio, the Director of Anthropology of the Mexican Government, as to the nature of the project to be undertaken at Chichen Itzá. Conferences were also had with Señor Don Ramon P. De Negri, the Minister of Agriculture and Public Works, and with General Obregon, President of Mexico, and on June 5 the formal proposition of the Institution was presented to the Mexican Government.

Dr. Morley spent the month of June in Mexico City arranging the details of the agreement with Dr. Gamio, of the Direction of Anthropology.

This contract (signed by the Minister of Agriculture and Public Works, representing the Federal Government of Mexico) concedes to the Institution "permission to carry out archæological explorations and excavations as well as all such repairs and restorations as may be necessary in the ruins of Chichen Itzá, in the State of Yucatan, . . . for a term of 10 years beginning January 1, 1924."

Although the contract does not come into operation until January 1, 1924, under article 20 the right was given to commence immediately certain preliminary work, such as clearing away the forest growing over that part of the city which it is planned to excavate first, and constructing field-quarters for laborers and staff.

In conformity with this clause, Dr. Morley left Mexico City for Yucatan on July 12 and visited Chichen Itzá in company with Dr. Gamio and Mr. Reygadas of the Direction of Anthropology. The Group of the Thousand Columns was selected as the first point for intensive operations, and early in August the felling of the forest over this area was commenced, and the nature of the work to be undertaken was fully discussed with the responsible officials of the Mexican Government on the ground.

In December Mr. J. O. Kilmartin, by arrangement with the United States Geological Survey, went to Chichen Itzá to survey the property which it is proposed to rent for field-quarters and to make a preliminary map of the Group of the Thousand Columns, as well as to supervise the construction of additional quarters for members of the scientific staff and the Maya Indian laborers. Dr. Morley returned to the United States on August 29 and spent the autumn in organizing the Chichen Itzá project. The members of the staff are to take the field early in January 1924.

During the course of the field season it was possible, from time to time, to further the general work on the Maya inscriptions by the discovery of a few new texts, of which three were found to have Initial Series.

At Chichen Itzá on March 6 a new stela was found in the niche between the double stairway on the west side of the second terrace leading to the Caracol or Round Tower. This monument has 132 hieroglyphs sculptured on its front, sides, and top, and is the longest inscription yet found at this site. It has not yet been possible to decipher the date, although its hieroglyphs are well preserved.

Underneath this stela was found a large circular stone with a projection for tenoning it into a wall. On the front of the round part twelve human figures are sculptured in two lines before an altar, arranged as if engaged in some sacrificial rite. A double row of hieroglyphs around the periphery completes the carving on this unique piece of Maya sculpture.

Several new inscriptions were located in the National Museum of Archæology and History at Mexico City; a small stela from Ocosingo, or more correctly from the archæological site of Toninâ near by, and two stelæ and a small round altar of unknown provenance, probably from the Usumacintla Valley.

The Toninâ stela is short, like all the monuments at this site. Although it is not more than 4 feet high, it is a perfect example of a Maya stela; the front is sculptured with a typical Maya figure, priest, ruler, or deity, holding in his arms the Ceremonial Bar. The back is inscribed with a double column of hieroglyphs surmounted by an Initial Series introducing-glyph. The inscription is badly effaced, though the katum coefficient is almost certainly below 11 and the tun coefficient is surely 0. The best reading of the Initial Series would appear to be 9.7.0.5.9, though this is far from satisfactory.

The other two stelæ mentioned above, as of unknown provenance, are, on stylistic grounds, probably to be assigned to the Usumacintla Valley. One of them has a human figure in profile upon its front and an Initial Series on its back. This reads quite clearly 9.12.0.0.0. The other, also sculptured with a human figure in side presentation on its front, has the day 9 Ahau carved in a conspicuous position before this figure. On the assumption that this day fell on a katun-ending, there are two possible readings in Baktun 9: 9.6.0.0.0 9 Ahau 3 Uayeb and 9.19.0.0.0 9 Ahau 18 Mol; neither is particularly satisfactory, the former being as much too early as the latter is too late.

The small, round altar at the National Museum of Archæology and History is a beautiful example of Maya sculpture from the Great Period of the Old Empire. It portrays a small, seated figure facing to the left and holding in its hand a platter containing an object which may be the sun-sign. This is surrounded by a circle of 15 hieroglyphs, of which the ninth (commencing at the top and reading clockwise) is the day 13 Ahau; the fifteenth is the day 9 Ahau. These two days are just 1 tun apart, if read in this order, and if it be assumed that the day 9 Ahau also corresponded with a katun-ending as well, the Initial Series, 9.19.0.0.0 9 Ahau 18 Mol could be assigned to this piece, not an improbable reading on stylistic grounds.

Before leaving Mexico City, Dr. Morley also examined the important Stone of Chiapa,[1] through the courtesy of its owner, Señor Don Emilio Rabasa. This piece is only about one-third of the original monument, which must have been between 6 and 7 feet high. The front is sculptured with the head and shoulders of a human figure facing to the left, with an elaborate head-dress; opposite the head are the remains of a single column of six or seven beautifully carved, but very small, hieroglyphs, each 1.5 inches square. The significant point is that the first glyph which remains has a coefficient of 9 surely, and the next one of 16, 17, 18, or 19,[2] and the next two possibly of 0 each. Could this be the Initial Series 9.19.0.0.0 with the Initial Series introducing-glyph effaced? The style of this monument indicates that it dates from the most brilliant epoch of Maya art, namely, the Great Period of the Old Empire, 472–630 A. D.

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[1] Drawings of both sides of this stela were published by D. G. Brinton in his "Primer of Maya Hieroglyphs," Series in Philology, Literature, and Archæology, vol. III, No. 2 of the publications of the University of Pennsylvania, figure 82.

[2] The drawing of the front of this monument published by Brinton, see *ibid*, figure 82, incorrectly shows this coefficient as 12. The original, however, has clearly 3 bars in addition to at least one dot.

It is the inscription on the back, however, which gives this monument its principal importance. This is presented in four columns, of five hieroglyphs each; the Secondary Series in the first two columns is apparently composed of 8 orders of units, involving possibly the highest Maya time-period known, the great-great-great cycle.[1] It is unfortunate, therefore, that it has been impossible to connect this Secondary Series either with one or the other of the two Calendar Round dates on the back or with the other Secondary Series of 2.14.15 present.

The first week in May was devoted to excavating two small temple-sites at the ruins of Quirigua, Guatemala: The Temple of Stela S in the banana-fields of The United Fruit Company, about a kilometer southwest of the main group, and The Temple of Stelæ T and U, about 1.5 kilometers behind the Quirigua Hospital, on the highest point of the first range of hills on the northern side of the Motagua Valley. The former proved to be only a foundation-mound composed of two platforms, the lower 2 feet high with a battered wall, and the upper 4 feet high with a vertical wall. On the summit were traces of a third very low platform, one step high. A stone stairway on the south side, now in ruinous condition, gave access to the summit. There were no vestiges of any former superstructure; and if this foundation-mound had ever supported one, it must have been built of some perishable material. The monument associated with this mound, Stela S, stands about 50 yards in front of the center of the south side, facing south, and dates from 9.15.15.0.0

Very little material was recovered during the course of the excavations—no whole pieces of pottery, and only a few potsherds and obsidian flakes. These were turned over to the Minister of Public Instruction, in accordance with the terms of the permit, at the conclusion of the excavations.

The Temple of Stelæ T and U was completely excavated. It faces the valley, i. e., south, and contains but a single small chamber, 10 feet 2 inches long by 3 feet 8 inches wide, which had been floored with stone flags. A single doorway 5 feet 6 inches wide in the southern wall gives access to it. The walls are 5 feet thick. Further attempts were made to decipher the Initial Series of Stelæ T and U, but unsuccessfully. The former dates surely from Katun 14, 9.14.0.0.0 being the best reading, and on stylistic grounds Stela U is probably not more than one katun later, i. e., 9.15.0.0.0.

In 1921 a splendid cache of 24 eccentric-shaped flints (now in the Ministry of Public Works in Guatemala City) was found either in the southeastern corner of this chamber or in the hearting of the eastern wall. The excavations this season yielded only a few obsidian flakes.

Dr. Morley was at Copan for three days in May. Three fragments of early stelæ had been found, in tearing down the walls of the house at the west end of the block on the north side of the village plaza, and had been placed in the *cabildo* for safe-keeping. None has any decipherable calendrical hieroglyphs, but on stylistic grounds all three may be assigned to the early part of Baktun 9.

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[1] Attention has already been called to the importance of this Secondary Series in "The Inscriptions at Copan," publication No. 219, Carnegie Institution of Washington, note 2, page 281. It appears to be composed of 8 orders of units with the tuns omitted. The number probably recorded is 13.13.13.1.1.0.11.4. The only other Maya number known, involving 8 orders of periods, is the Initial Series on Stela 10 at Tikal: 1.11.19.9 3.11.2.0.

One of the most spectacular caches of jade in the Maya area was found on April 2, 1921, at Copan, just west of the northwest corner of the mound of Stela 7, in a cruciform vault below the foundation-stone of some Early Period stela.

About 6 inches below the level of the cement floor on which the mound of Stela 7 was built, a large slab of stone 5 feet 1 inch long, 2 feet 9 inches wide, and a foot in thickness was unearthed. This would appear to have been the foundation-stone upon which one of the several Early Period stelæ, found in the immediate vicinity, had rested, though just which one it is impossible to say. This foundation-stone in turn lay directly upon a large circular stone 3 feet 9 inches in diameter and 9 inches in thickness, which in turn covered the cruciform vault. At the intersection of the axes of this vault was found the cache above mentioned. This contained the following objects of jade: 1 anthropomorphic statuette 7.25 inches high and weighing 2.5 pounds; 8 jade pendants carved with representations of the human figure or grotesque animals; 2 pairs of round ear-plugs; and 2 long tubular beads. Also, there were 38 sea-shells, *Spondylus calcifer;* 3 shell beads; and a small quantity perhaps enough to fill a 2-ounce bottle, of quicksilver.

Two or three yards east of this cache was found a human burial with a number of jade objects: beads, ear-plugs, several small figures; also sea-shells and quicksilver. In 1919 Dr. Morley found three pieces of beautifully worked jade not more than 4 yards south of the above burial, in the northwest corner of this mound, practically on the surface: an anthropomorphic figure 3 inches high, pierced for use as a pendant, and the two halves of a jadeite pebble, from each of which a small cylinder had been cut out, probably for making into a pair of ear-plugs.[1] Finally, the Museum of the American Indian, Heye Foundation, has a large jade pebble with a beautifully carved seated human figure on the front, which came from the cruciform chamber under the foundation of Stela 7.[2]

The stylistic characteristics of these objects indicate that they all date from the Early Period of the Old Empire, which is in agreement with the dates actually recorded upon the stelæ found on or around this mound, i. e., 9.2.10.0.0 (Stela 24) to 9.9.0.0.0 (Stela 7). The jade objects found on or around this mound easily constitute the largest and most important collection of early Old Empire jades known anywhere.

Concerning the work of Messrs. Love and Ricketson in determining the latitudes and longitudes of 12 of the largest archæological sites in northeastern Peten, an abstract of the former's report thereupon, together with the latitudes, longitudes, and magnetic elements of these several stations, is published in the report of the Director of the Department of Terrestrial Magnetism. See pages 261, 262.

The archæological reason for this particular investigation was to ascertain the exact geographic positions of these different sites, from which data it would be possible to make an accurate map of the northern Peten region, i. e., the very heart of the Old Maya Empire, showing the relative positions and distances apart of its largest centers.

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[1] Carnegie Inst. Wash. Pub. No. 219, pp. 103–105.

[2] The other objects which were found in this chamber were: A sea-shell (*Arca grandis*), a stone with a hole through it, an obsidian spearhead 7 inches long, another of the same material slightly longer, an obsidian knife 6 inches long, and a small fragment of an Early Period stela, V′14. See *ibid*, p. 105

The area in question is not large, a 50-mile square in the northeastern corner of the Department of Peten practically comprises it, and none of these sites are far apart in an air-line.

Some surprising and, in view of existing highways of travel (the only too casual and round-about chicle-trails), disconcerting facts developed therefrom. For example, it takes a mule-train, over existing trails, two days to go from Xmakabatun to Xultun, which are only 11.4 miles apart, and other instances of the proximity of these cities one to another might be cited. Indeed, no two of them are so far apart as to require an Indian on foot more than a single day to travel between them, and some of them, as, for example, Tikal and Uolantun, are so close together, 3.5 miles, that they must be regarded as parts of the same city.

Evidence multiplies that this section of the Old Empire was one of the most densely populated areas of its size in the whole world during the first six centuries of the Christian era, and the occupation of the land between the different larger centers, like Tikal, Uaxactun, Xultun, Nakum, Naranjo, etc., must have been practically continuous.

Report of Mr. J. O. Kilmartin on the Topographic Survey of Lake Peten.

The object of the topographic survey of the Lake Peten region was to ascertain whether or not the peninsulas of San Benito, Candalaria, and Tayasal were islands, as described by the different Spanish conquerors and padres at the time of their *entradas*, between 1525–1697, and which was the Peten Grande, or Island Capital of the Peten Itzas, and what rise of water would be necessary to convert these present peninsulas into islands.

On the peninsula of San Benito a trail leads from the village of San Benito at the point, across the mountains to San Juan de Dios, La Libertad, and other villages. Only one place was found along it (at the trail-forks and inclosed by the 490-foot contour) that might have been an island, and this certainly was not so at the time of Father Avendaño's visit to Tayasal in 1697. For about a mile back from the lake shore the topography is fairly regular—that is, it is not broken up by small drains. This section was an old lake-bed at one time. In front of the cemetery in San Benito is a small saddle, elevation 425, and just to the north, extending along the peninsula, is a small knoll inclosed by the 430-foot contour, but this is not to be considered.

While traversing the trail to Picu west of San Benito, a good view could be obtained of Candalaria Peninsula, and what might be the lowest place appeared to be about a mile back from the extreme end of the peninsula. A trail was cut into it and elevation established. Ruins were found scattered throughout this area; practically all just above the 460-foot contour. The trail from San Geronimo Bay to Picu was next traversed and nothing was found tending to prove that Candalaria Peninsula was ever an island.

The third and most important peninsula under consideration is that of Tayasal, which many have thought to be the Island Capital of the Peten Itzas. After traversing the trail to Pitchallin, a line of levels was carried south to Naranjal, along an old trail which passes through a low gap on the 565-foot contour, then dropping into a *bajo* (low ground), elevation 520, and thence into the drainage of Lake Eckixil, which is west. At Naranjal the line continued in a southwesterly direction across the foothills and on to El Yex. From El Yex the line continues to San Benito, thus completing a circuit around the entire area involved. From Playa Trapiche a trail follows east along the peninsula of Tayasal. At the road-forks, elevation 620, one trail continues to Sonoti and thence to Playa Puxtial, while the other continues south and east across the divide between Lake Peten and Lake Petenxel to the intersection of the trail from El Yex to San Benito.

From a point along the trail from Sonoti to Playa Puxtial a trail was cut east to the saddle on the Pitchallin-Naranjal line. No lower place than that previously discovered, i. e., 565, was found, and the elevation checked favorably with the one before, which is one of the proofs that Tayasal was not an island. In the village of Flores and just below the plaza on its north side, certain glyphs are inscribed on a rock ledge, exactly 50 feet above the lake-level, and it is likely that these were somewhere close to water-level a few hundred years ago.

Lake Peten contains ten islands, of which only two, Flores and Lepet, are inhabited; the remainder are of no great importance, as they show no evidences of ruins or of having been inhabited at any time. Indeed, all except Santa Barbara, Flores, Hospital Island, and the last island to the east of Flores are of recent origin, and even Lepet may also be included in this list.

To the east of Flores and Lake Peten are two large and two small lakes, the small lakes being at no time connected with the larger ones. Lake Petenxel is 13 feet above Lake Peten, Lake Eckixil is 18 feet above Lake Petenxel and 31 feet above Lake Peten, and a 20-foot rise of water in Lake Eckixil would connect all of these lakes.

In Lake Eckixil are two small islands; on the island to the west are ruins of perhaps one house, just above the 460-foot contour. These ruins are of the same type found elsewhere throughout this region. Residents report that the water rises but little during the rainy season.

The Savana de Sonoti has many ruins similar to those on the western end of Tayasal, and two tombs found there appear to be of the same type as the one excavated by Dr. Guthe at Tayasal in 1922. Just west of the intersection of the trail to Sonoti and San Benito is a saddle 15 feet lower than the one between Pitchallin and Naranjal; this also would tend to prove that Tayasal was never an island.

In drawing conclusions, we must, first of all, consider the hieroglyphs in Flores, elevation 50 feet above lake-level. It is certain that these were not inscribed under water, and therefore in order to convert Tayasal into an island we must look for a saddle with an elevation that compares with this.

On Candalaria Peninsula 65 feet of water would be necessary to convert the small knolls shown into islands, but this would obliterate the ruins. From this we can readily see what effect 150 and 165 feet of water would have on these places.

It is hoped that the foregoing facts, with the aid of the topographic map obtained, clearly prove that the present peninsulas of San Benito, Candalaria, and Tayasal were not islands as described by Father Avendaño in his sketch of Lake Peten in 1697. It is most likely that the present Tayasal was the capital city of the Itzas, but certainly it was not an island, and the padres were either wrong in their descriptions of it, or in their interpretation of the Maya language.

Van Deman, Esther B., Rome, Italy. *Associate in Roman Archæology.* (For previous reports see Year Books Nos. 9–15, 20, 21.)

The year has been wholly spent in the publication of the first three of the series of papers dealing with the structural history of the more important monuments studied during the last ten years, especially those of the Forum, Sacra Via, and Palatine. Owing to the mass of material on hand, it was found necessary, in the three articles now completed, to limit the publication at this time to a full description and special plan of the remains of the most important of the new periods so far determined, which may serve as a point of reference, or datum, in later investigations, with a brief review only of the other periods. The first quarter of the year was devoted to the paper on the Forum of the period of Sulla,[1] the discovery of which was noted in the previous report. In connection with this discussion, a brief résumé was given of the levels and orientation of the Forum at the various periods, with a plan of the four greater levels, two of which have not been recognized as such. The remains of several new monuments built or rebuilt in the Sullan period were discovered or identified, the most interesting of which are the Græcostasis, the fornix Fabianus, the Lacus Servilius, and a possible porticus in front of the *tabernœ Novœ* on the north. A few scanty remains were found also of the first permanent pavement of the Forum area, which was the work of Sulla. The second paper, to which the following four months were given, consisted of a discussion of the region of the Sacra Via of the later Neronian period,[2] with a résumé of the earlier periods, especially with respect to their level and orientation. Following the general lines of the great work of the School of Engineers of the University of Rome, a new plan of the whole region was made to serve as a basis for all future publications. In addition to the extensive remains of the Sullan period already reported, the more important of the pre-Neronian monuments discovered or identified are the temple of the Penates on the via leading to the Carinæ and an Augustan arch in front of the domus Augustana on the Palatine, the remains of which have been assigned to the period of Domitian. Extensive new remains of the following periods of Domitian, Hadrian, and the Severans were also identified and partly classified for a later paper. The later months of the year were devoted to the completion for publication of a paper on the palace of Caligula at the northwest corner of the Palatine, by which he united it to the Forum below.

In connection with the more intensive examination of the remains under consideration rendered necessary by their publication, a considerable body of new material has been collected for the more general work on the methods of construction. In the main this material consists of the remains of a number of new dated monuments of the periods of Sulla, Julius Cæsar, Augustus, and Hadrian, in addition to the vast structures of Nero, Caligula, and the Severans.

Many thanks are due to the American Academy in Rome, not only for the use of their library, but especially for the valuable assistance rendered during the year by the various members of the staff. A number of investigations have been undertaken by members of the School of Classical

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[1] The Sullan Forum, Jour. of Roman Studies, xii (London), pp. 1–31, plans I–II and plates.
[2] The Neronian Sacra Via, Amer. Jour. of Archæology, 1923, 4, with 2 plates.

Studies, under the direction of the professors, which promise valuable help in the classification of certain monuments.

The list of monuments accepted as being dated after examination of the whole mass of evidence, both external and internal, was in part published in 1912 in the American Journal of Archæology under the title "Methods of Determining the Date of Roman Concrete Monuments." Since then the list of uncertain monuments has been reduced to a very small group and many undated monuments have been identified, affording much additional material for the scientific chronology of Roman monuments and the creation of a critical canon of construction. This material is in large part being prepared for publication in the "Handbook of Roman Construction," which will soon appear.

In the compilation of the new chronological list of dated monuments from which the canon of construction is to be drawn for the dating of the extensive and fast-vanishing remains in concrete, the external evidence for which is lacking or incomplete, a fixed method of procedure has gradually been developed. The University of Rome, as well as the various schools of archæology, now require, in all research work concerning the monuments, a knowledge of this method, which provides for the analysis of the monuments according to the core of their structure and according to their facings.

In order to show a little of the range and extent of the analysis of the monuments already completed, the following list has been added, giving a part of the meaurements made for determining the types of brick facing. For each monument ten groups of typical bricks of ten each in unrestored parts of the structure have been examined and listed for length and thickness, width of the horizontal and vertical joints of mortar between them, color, composition, fineness of texture, puddling, etc. Where possible, ten monuments of a period are included as the basis for final conclusions in the canon of construction.

	No. of measurements.
Augustus: Rostra Augusti, Domus Publica, tomb of Cæcilia Metella	300
Tiberius: Castra Prætoria, tower at Capri	200
Caligula: Domus Caligulæ	100
Claudius: Aqua Claudia and anio Novus, port of Ostia	200
Nero: Atrium Vestæ (200), shops on north of same, arcus Neroniani, Palatine (300), temple of Claudius, port at Antium (also many monuments measured from Pompeii, Ostia, etc)	1,000
Vespasian: Colosseum, aqueducts	200
Titus: Temple of Vespasian, porticus of Dei Consentes, aqua Marcia and aqua Claudia	200
Domitian: So-called Temple of Augustus, Domus Tiberiana, stadium, aqueduct to Palatine, aqua Claudia, and anio Novus, villa at castel Gandolfo	800
Trajan: Thermæ, forum, aqueduct, thermæ of Sura, amphitheatrum Castrense (Port of Ostia and work at Beneventum not used for canon but completed)	500
Hadrian: Tomb, pantheon, domus Tiberiana, Nova Via, and ramp, Sacra Via, atrium Vestæ, domus Augustana, porticus belonging to the Colosseum, aqueducts (500), villa, temple of Venus and Roma	1,500
Antonines: Atrium Vestæ, thermæ at Ostia	100
Severans: Atrium Vestæ, arcus Neroniani, stadium, palace on the Palatine, thermæ of Caracalla (200), aqua Claudia and anio Novus (200), aqua Alexandrina, colosseum	1,000
Aurelian: Thermæ of Caracalla, wall	100
Diocletian: Thermæ, curia	200
Maxentius: Basilica, temple of Venus and Roma, so-called temple of Romulus, arcus	400
	6,800

Washington, Henry S., Washington, D. C. *Report on ancient Roman building materials.*

During June, July, and August, 1922, I collaborated with Professor Tenney Frank, professor of Latin at Johns Hopkins University, in studying the mortar, brick, and tuff used in the buildings of ancient Rome. The investigation was undertaken following a suggestion by Miss Van Deman (in Year Book No. 21) that for a number of years "an exhaustive chemical and microscopic examination of the Roman bricks and mortar of the different periods" has been felt to be advisable. A study of the Roman volcanic tuffs was included because they form one of the earliest and most important of the ancient building materials.

Especial attention was paid by us to the ruins in the Forum Romanum and on the Palatine Hill, where every ancient building was examined from the point of view of its material, its known history and restorations being also considered. Some specimens of construction materials of all three classes, mortar, brick, and tuff, were collected from many of the buildings. Our study and the collection of specimens were greatly facilitated and, indeed, rendered possible by the interest shown in the work by, and the cooperation of, Commendatore Giacomo Boni, Director of the Excavations at the Forum and the Palatine, and his First Assistant, Ingegnere Torquato Ciacchi. Many quarries of tuff, both ancient and modern, were visited and specimens of the material were collected. The occurrence of these volcanic tuffs and their uses in early Roman architecture have been a special study of Professor Frank.

The purposes of the investigation are twofold. The chief one is archæological, and this has several special objects in view. One is the determination of the chemical and mineral characters of the material and the composition of the mortar, brick, and tuff, as a contribution to the study of Roman architecture, for which a better knowledge of the characters of the materials is desirable. Another is the classification of the three kinds of material, based on the chemical, mineral, and textural characters, the classifications being so devised that they may be usable by archæologists without such special knowledge; that is, the classifications should be, so far as possible, expressed in the megascopic characters. The provenance of the various materials and of their components (as with mortar) should be ascertained. In a given mortar, for example, we should know whether it was made with the admixture of powdered brick or of pozzolana, and in the latter case whether the volcanic material came from the neighborhood of Rome or of Baiæ. The correlation between the characters of the material and the builders who used it is the most important archæological problem. Various materials were commonly used at different times and, especially, the different Roman emperors who were most active in building operations had their favorite or usual kinds of construction material, whether tuff, mortar, or brick, which are thus more or less characteristic of their work. It is possible by such correlations, even in the absence of stylistic, epigraphic, or literary evidence, to determine the original builder of a temple, basilica, or other construction, and those who restored or altered it in later times. In this way the important dates in the history of many ancient Roman buildings may be traced with considerable accuracy and certainty. Dr. Van Deman, in her work at

Rome during the past years, has made a special study of this aspect of the subject, with much success.

Such correlations should prove to be particularly useful in the future excavations at Rome, as at the Imperial Fora, north of the Forum Romanum, and the principles and general lines of investigation may well be applicable also at the future excavations at Chichen Itza under Dr. Morley.

The other purpose is technical and applies chiefly to the mortar. The Roman mortars offer excellent opportunity to study certain problems in the characters and changes of the material that may be of useful application to the study of modern cements. They are of special interest and importance for the study of the changes brought about by the very slow chemical reactions between the constituents, such as lime, sand, powdered brick, and pozzolana, and, consequently, the characters that make for durability. The Roman mortars have undergone a time-test of nearly 2,000 years under conditions of actual use, a most severe test to which it is not possible, for our study, to subject our modern materials. Some of them are still hard and coherent, whereas others, made about the same time and existing under about the same conditions, have become soft and friable. Study of the chemical, mineral, textural, and microscopical differences between such mortars should cast light on some of the factors that favor the production of a good mortar or modern cement, and so should be of interest and value to the cement industry. The ancient bricks and tuffs promise fewer results of purely technical interest, but a study of the Roman tuffs will be of interest for petrology and volcanology.

It is my purpose to make many chemical analyses of the specimens of all three classes of materials and study thin sections of them under the microscope; to study them, in fact, in much the same way that igneous rocks are studied. The objects of the investigation present certain difficulties, because of the vague and somewhat indeterminate characters of many of their mineral components, their generally fine grain, and the indefiniteness of their textures. The mortars also present certain special problems connected with their investigation for technical purposes, such as the character of the free or "soluble" silica and the states of combination of the lime. These will demand the working out, trial, and application of special chemical methods.

It is suggested that specimens of the mortars from the ancient Roman ruins near the modern Pozzuoli (the ancient Baiæ) be collected, because these will permit the study of the influence of the incorporation of the peculiar pozzolana of this region, which was most favored by Vitruvius and was considered to make the strongest mortar and to be particularly useful for the making of hydraulic cement. An examination of the brick and mortar of Pompeii might well be carried on in connection with the study of the Roman materials. At Pompeii there is a definite end point (79 A. D.), with the earthquake at 63 A. D. as another date, and the researches of Mau and others have enabled us to distinguish between the pre-Plinian building periods. The fact that much of the pozzolana used at Pompeii came from Baiæ adds interest to the Pompeiian materials.

BIBLIOGRAPHY.

Tasker, Arthur N., Army Medical Library, Washington, District of Columbia. *Preparation and publication of the Index Medicus.* (For previous reports see Year Books Nos. 2–21.)

The second volume of the third series of the Index Medicus (for 1922) comprises 1,050 pages of actual titles; 111 pages constitute the author index. The previous volume contained 1,126 pages and an author index of 116 pages. This slight decrease in size as between the two volumes was made possible by a more critical examination of all articles whose titles were to be printed, with a view to eliminating those that were either so short as not to give information in sufficient detail to be of outstanding value, or that offered nothing really new. This does not mean, however, that the actual volume of the world's medical literature has decreased, for such is not the case. In the 18 months that have elapsed since the beginning of 1922 the number of current periodicals (to say nothing of annuals, transactions, proceedings, etc.) indexed for the Index Medicus has increased from 1,608 to 1,875.

Very numerous testimonials have been received bearing witness to the favor in which users of the Index Medicus hold the new system of alphabetized classification. A few correspondents have expressed a preference for return to former methods. Editorial difficulties encountered in connection with that system in former days still exist, and would certainly present themselves anew were a reversal of policy to take place. One of the most impressive examples of the particular variety of problem referred to has already been described in the introduction to the present volume, but will nevertheless easily bear repetition. Of two men who had been asked for their views on the general classification of medical literature, one (a surgeon) was very insistent that all cancer should appear under the general caption of "Surgery," since early use of the operator's knife remains still the best hope for cure of that condition; the other (a pathologist) was equally definite in his conviction that all articles relating to cancer should appear in the Index Medicus under "Pathology," his argument being that the most important phase of cancer research is concerned with its etiology, and that this is preeminently the field of the pathologist. To satisfy both these petitioners would be manifestly impossible. All cancer is therefore classified under "Cancer," which thus constitutes for the surgeon and pathologist a sort of neutral zone.

The table of contents of each individual number continues to indicate the relations existing between the major and subsidiary subdivisions of medical science. A rapid survey of this table should be always introductory to the examination of each succeeding quarterly issue.

The primordial purpose of the Index Medicus has undergone no change in concept. It seeks to present, as compactly as possible, for those who have recourse to it the largest number of references to that portion of the world's literature having real value and dealing with medicine and surgery, their various disciplines and specialties, and their allied and associated sciences.

BIOLOGY.

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3–21.)

During the past year the general plan of investigation outlined in previous reports has been followed, to make an exhaustive study of the linkage relations of genes in mammals. Although several minor problems involved in this plan have been solved, it seems better not to attempt a report upon them at this time, but to postpone it until its bearings on general questions can be more fully discussed. The breeding operations with rabbits and rats have been very extensive and successful, and a number of stocks of particular genetic composition have been produced as the indispensable material for tests of linkage relations and for other purposes.

Two species of rat are being studied, *Mus norvegicus* and *Mus rattus.* The former is the one commonly used in laboratory studies and genetically the better known. But the latter promises to yield results valuable for comparison with those based on the Norway rat, the mouse, the rabbit, and the guinea-pig. We already have two different varieties of gray *rattus* and two of black, one variety of black being dominant, the other recessive in relation to gray. We also have a yellow variety recessive in relation to black or gray, and hope soon to obtain a blue variety reported from England and a cinnamon variety reported from Texas. An albino variety is much desired for linkage studies parallel with those which have been made in the Norway rat and in the mouse, but at present no such variety is known.

Upon the Norway rat studies are in progress of differential fertility in relation to inbreeding, and of the effects of X-rays upon the germ-cells. In rabbits a study is being made in cooperation with serological experts of the Massachusetts Department of Public Health, to discover if possible whether blood groups occur similar to those reported to occur in man and, if so, how they are inherited. Results so far are negative, but the experiments will be extended to wild species of rabbits as well as the domestic species.

Kofoid, Charles A., University of California, Berkeley, California. *Investigation on intestinal protozoa.* (For previous report see Year Book No. 21.)

Investigations have been continued on the incidence of human amœbiasis and *Arthritis deformans* of Ely's second type, in collaboration with Dr. L. M. Boyers and other physicians having clinical charge of patients suffering from this disease. The work is conducted with a view to the clearer definition by the physician of the clinical signs of the disease, and on our part by a clearer characterization of the types of amœbæ associated with the disease. Gratifying results in the detection (by persistent and repeated examinations) of a small form of amœbæ have been obtained. There are indications that there is a high degree of resistance established in the cases of supposed bone-marrow infection with resulting involution or dwarf stages of the parasite.

We have examined additional cases of Hodgkin's disease, with the result that in every instance but one there is accompanying amœbiasis of the bowel. In this one instance only a single specimen was available for examination. Some of these cases have been under treatment and observation with gratifying results to date.

Substantial progress has been made in the fuller study of variation within the several species of amœba parasitic in man, with a view to the more accurate delineation of their normal range of form during the processes of cell-division and encystment.

Medical literature has for many years contained accounts of flagellate diarrhœas attributed to Trichomonas. This literature is conflicting, and the pathogenicity of these flagellates has been generally denied in recent years with the resulting confusion of testimony as to the significance of these infections. We have, during the past year, had access to three cases of infection by the trichomonad flagellate which has been described as *Pentatrichomonas ardin delteili* from Algiers, Calcutta, and Manila. It is undoubtedly a pathogenic organism in the cases now under our observation. We have been able to clearly establish the fact that there are two types of trichomonad infections of man, one of which (*Pentatrichomonas*) is undoubtedly pathogenic, and we have been able to establish the characteristics by which it may be distinguished from the non-pathogenic form in life and in stained material. This rests upon the differential behavior of the flagella in life which hitherto has obscured the constancy of the differential numbers of flagella in the two genera.

In cooperation with Dr. J. F. Kessel, University of California Fellow in Zoology, parasitic amœbic infections of culture rats and mice have been studied. Three species have now been clearly diagnosed and their chromosomes counted in two cases. These two belong to our genus *Councilmania*. As a result of Dr. Kessel's experiments certain human parasitic protozoan infections have been successfully implanted in the intestine of culture rats and mice. This has been accomplished by the elimination of milk diet, the use of young rats after weaning, and the limitation of experimental infection to rats previously known to be free from their own species of amœba. Dr. Kessel has perfected a method of determining amœba-free rats by the use of epsom salts. This work adds a new weapon to the experimentalist in the attack upon the experimental study of human parasitic protoza. In conjunction with Dr. Kessel the experimental transfer of the human infections to the rat have enabled us to clearly establish the generic and specific identity of *Councilmania lafleuri* and the constancy of the characters which differentiate it from *Endamœba coli*.

This is a matter of greatest clinical significance, since *Councilmania* has clear pseudopodia and this characteristic is very generally used at the present by clinical microscopists to diagnose *Endamœba dysenteriæ*, the etiological factor in human amœbiasis. The presence of *Councilmania* would, therefore, lead to false diagnosis, if reliance is placed upon clear pseudopodia. It will be necessary in the future, and will now be possible, to guard against this mistaken diagnosis.

The study of Giardiasis in dogs and the transfer of human infections by *Giardia enterica* to the dog have been successfully accomplished in dogs by Miss Howitt in our laboratory. It is highly probable that the dog may prove to be a carrier for this human infection, especially in children. Studies are now being conducted in experimental therapeutics of these *Giardia* infections in dogs.

Dr. Olive Swezy has assisted in the work with these human infections.

Mann, Albert, Washington, District of Columbia. *Continuation of investigations and preparations for publication of results of work on Diatomaceæ.* (For previous report see Year Books Nos. 18–21.)

Diatom investigation this year has progressed more satisfactorily than in previous years, as adequate help for handling the ever-increasing quantity of material sent to the laboratory has been secured. Mr. Paul S. Conger and Mr. L. B. Copeland have joined the laboratory force and have taken up this line of investigation with the intention of making it their permanent vocation.

As it has become more generally known that reports on diatom deposits, fossil or recent, were available, there has been a steady increase in the number of requests made for analysis. During the year 17 consignments of fossil diatom material (amounting to 116 samples), and 8 of recent material (amounting to 231 samples) have been accepted, studied, and reports thereon made. Several of the fossil class had to do with commercial problems of immediate economic value.

Two investigations deserve special mention here. Professor A. N. Winchell, of the University of Wisconsin, sent in three samples of dust from the upper atmosphere, brought down by snow-storms at or near Madison, two of which contained diatoms. Atmosphere diatoms were known to exist, but these samples contained several species not hitherto found in such material. The other remarkable case was that of a sub-fossil diatom flora found in an ancient bald-cypress swamp, uncovered during building excavations at De Sales Street and Connecticut Avenue in Washington, D. C., in November 1922. Studies of the swamp material were made by several scientists interested in the various organisms discovered in it, as well as a general survey of the geology of the deposit. Papers were prepared, and were read at a meeting held under the auspices of several of the Washington scientific societies. The diatom paper proved to be especially serviceable in determining the character, climate conditions, and approximate age of the swamp, because of the larger number of species found than of those of the other groups, and their much better preservation. 78 species were obtained, only a meager percentage of which are now living in this locality or in bald-cypress swamps existing in this part of the country; but a large proportion of them were seen to be identical with those composing the Pleistocene fossil diatom beds at Montgomery and Cunningham, Alabama, and a sub-fossil bed at Crane Pond, Massachusetts. The correspondences with the latter were over 82 per cent.

The work at Woods Hole, Massachusetts, is now in its seventh consecutive year and is therefore nearing the time when a sufficiently long series of observations will afford trustworthy data on the seasonal variation of species and the relative abundance of diatoms in that vicinity in relation to the food supply of marine fishes, clams, and oysters. Six weeks were spent there this summer, and ample collections were made for carrying on this line of study.

During the year the preparation of the manuscript on the Philippine Islands diatoms has been finished; the study of the diatoms of the Canadian Arctic expedition has been about completed, and all the material of the Australasian Antartic expedition has been prepared for examination and more than half of it examined.

Two years ago a trip of three months was made to the Pacific Coast, the main object of which was to start diatom research at favorable localities that should be cooperative between scientific workers of that region and the laboratory in Washington. The plan was favorably received and some excellent work has since been done, but in the meantime it has seemed advisable to make a second, shorter trip over part of the same territory. This was done, April 28 to May 28. Conferences were held with scientists at San Diego, La Jolla, Laguna Bay, Los Angeles and vicinity, including the new station at San Pedro, not yet in operation at the time of the former trip, and the territory about San Francisco. The Puget Sound area was omitted, as the stations there were not yet opened; and Pacific Grove, California, was also left out, as the work there seemed to need no stimulation. An invitation to revisit Lompoc was declined as being unnecessary; but two microscopists from there came to Los Angeles and a day was spent in demonstrating methods of diatom study. While at Los Angeles an illustrated lecture, under the auspices of the Brenner Club, was given to men associated with the California petroleum business on "The probable relation between diatom beds and petroleum deposits."

The trip brought out the fact that the main difficulty in the way of diatom study on the Pacific Coast is a lack in diatom literature. To somewhat compensate for this handicap an offer was made to supply the stations with sets of mounted diatoms representing the common species of the local flora—in other words, authentic types by which most of the diatoms of each locality can hereafter be recognized, further mounted specimens to be added as other forms are discovered. The plan met with approval and will greatly stimulate interest in the work. A set of 48 species has already been made and sent to Dr. W. K. Fisher at Pacific Grove.

A large amount of diatom material has been distributed during the year to parties interested in their study in this and other countries. The diatom collection at the U. S. National Museum has been greatly improved.

McCracken, Isabel, Stanford University, California. *Studies in silkworm bionomics.*

In the spring of 1920, eggs of five races of silkworms were received at the Stanford Entomological Laboratory from Japan through the courtesy of Mr. M. T. Kagayama, Director of the Imperial Tokyo Sericultural Institute, and Mr. S. I. Kuwana, Director Imperial Plant Quarantine Station, Yokohama.

Italian Alpine, dichromatic as to larval color (zebra and white of so-called normal pattern) and buff cocoons.
French Sezart, dichromatic as to larval color (moricaud and white), dichromatic as to cocoon color, white and buff (white prevailing).
French Lucien, dichromatic as to larval color (zebra and white of the so-called plain type) and buff cocoons.
Japanese White, white larva of normal pattern and white constricted cocoons.
Chinese White, white larva of plain type and white oval non-constricted cocoons.

On the basis of certain work in silkworm bionomics[1] carried out by Dr. Kellogg and his students at Stanford University from 1900 to 1912, this material was utilized by the author in 1920–21 and again in 1921–22, in a set of breeding experiments designed as follows:

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[1] 1908, Kellogg and Bell, Inheritance in silkworms: I, Stanford University Publications No. 1; other papers, and much unpublished data.

1. To test the relative genetic values of color characters of larva and cocoon as exhibited in parental lots, as to their conformity with previous results.
2. By interbreeding within these lots to secure pure strains with reference to certain characters.
3. To test the effect of interbreeding as measured by fertility or other indicators.
4. To discover the genetic or other physiologic relation of the many color-shades exhibited in hybrid crosses.
5. To test the effect of various influences (interbreeding, and certain environmental conditions) on the product of the salivary glands, namely, the silk.

As a result of Experiment 1, the genetic status of larval and cocoon-color characters, as exhibited by the various races to be used in further experimentation, was established by the work carried on in 1920 to 1922.

Ninety broods of worms, running from 100 to 300 worms in a brood, were under constant surveillance during the spring and summer of 1923. In certain lots, material has been secured study of which will give data for comparing the effect of cross-breeding versus interbreeding in this material, and eggs have been obtained for continuation of this series of work.

In lots of silkworms reared under various conditions of temperature and humidity, material has been secured to test the effect of these conditions on the salivary glands and their secretion, namely, the silk. This material is, however, limited as the conditions proved too strenuous for the worms and many fatalities resulted. However, sufficient material was secured to produce, when studied, tentative results, which will form the basis of next year's work along this line. A serimeter has been secured for testing the breaking strength of the silk fiber.

The relations of color of blood in the silkworm to color of the cocoon, and to the color of the egg and the "breaking" of cocoon-color in hybrids, are being studied.

Sufficient broods of eggs have been secured from the lots reared this year, to serve for the continuance of the project in 1924.

Morgan, T. H., A. H. Sturtevant, and C. B. Bridges, Columbia University, New York. *The constitution of the germ-material in relation to heredity.* (For previous reports see Year Books 15–21.)

Since our last report about 40 new mutants have been added to our stock. The most useful are the new dominants that are especially suited to experiments involving crossing-over. Their use avoids the necessity of first making up double recessive stocks. Among the new dominants may be mentioned:

(1) A bristle mutant, called stubble, half a unit to left of spineless in chromosome III.
(2) A beaded-in-X (called beadex), whose locus in the X-chromosome is to the right of bar and close to fused.
(3) A crumpled wing (jammed) whose locus (at 39) is between dachs and black, in chromosome II.
(4) A new minute (*i*) between hairy and dichæte, in chromosome III, that will be useful in studying the large cross-over fluctuations in that region.
(5) Another minute (*j*), three units to the left of rough in chromosome III.
(6) A minute (*m*), about 30 units from lobe, in chromosome II.
(7) Lobe-^{3}, an allelomorph of lobe, more extreme than lobe but less extreme than lobe-^{2}.
(8) A bristle mutant (off) in which a few bristles are absent from the abdomen, leaving the sockets as in hairless.

The last mutant is not lethal when homozygous, as are so many other dominants. In the pure form (homozygous) the eyes are rough, but not in the hybrid. Hence the mutant may be used as a dominant with reference to one character, and as a recessive with reference to another.

Among the new recessives calling for special mention is rose eye-color, to the left of dichæte. This mutant, along with minute-i, will make it possible to explore the region between hairy and dichæte (15 units long). The males are sterile, but the females are fertile. Another mutant, called lance-b, having narrow wings, is a recessive in chromosome II. It also has sterile males. A third recessive mutant, called parted (because the thoracic hairs diverge in the mid-line) has sterile males. The genitalia are rotated through 180° from normal. A fourth mutant called deltex (delta-in-X) looks like the dominant delta in chromosome III, but is a recessive in the X-chromosome, lying between crossveinless and cut.

These and other mutants have been used in improving the maps. Some of the old loci have been more accurately placed. Thus, warped, instead of being to the right, is to the left of pink; and curled, instead of to the left is found to be two units to the right of pink. This region to the right of pink is peculiar with respect to crossing-over, and the position of curled will make it useful for further study of this region.

Several new multiple stocks, including some of these new mutants, will make it easier to work with almost any new problem that arises. This is especially true for chromosomes III and I. In chromosome I a set of stocks has been made with alternating loci that will permit a study of this entire chromosome in almost any degree of detail. Other stocks have been freed from characters that in the past have limited their usefulness.

Balanced stocks have been found advantageous in keeping certain mutants, which, because of sterility or low viability or the lethal nature of the homozygote, could not be maintained without selection of particular types of parents in each generation.

The mutant used in balancing must be itself a type that is lethal when homozygous, or poorly viable, or sterile. The absence of crossing-over, that is also essential for balancing, may be due either to the closeness in the chromosome of the genes concerned, or to the presence in one or the other of the homologous chromosomes of a dominant crossing-over suppressor. A few examples of the way in which balanced stocks are prepared will serve to illustrate some of the advantages of the *Drosophila* material. Minute-h is lethal when homozygous. Its locus is within two-tenths of a unit from that of dichæte, which is also dominant and lethal when homozygous. The latter can be used to balance minute-h when the two genes are in opposite chromosomes. Practically all the flies in such a balanced stock will continue to be both minute and dichæte without selection. Half the offspring from an outcross will be minute-h, the other half dichæte; and since the balancer (dichæte) has been separated from the balanced (minute-h) either form can be used as if it had come from homozygous stock.

The new mutant rose, whose males are sterile, has been maintained in balanced stock by the presence in the opposite chromosome of a new crossing-over suppressor with an associated lethal.

It may be also worth while to show by way of illustration how the possession of balanced stocks makes it possible to work out the inheritance of certain characters which would otherwise present unusual difficulties. The new mutant, no-wing, has sterile females and rarely fertile males. Only a small percentage of the mutant flies emerge, and those live only a few days. In order to carry on this stock it had to be balanced. A male was crossed to a curly female. Curly is a dominant which carries a dominant cross-over suppressor in chromosome II. When the F_1 curlys are inbred $\left(\frac{\text{curly}}{\text{no-wing}} \text{ by } \frac{\text{curly}}{\text{no-wing}}\right)$ the offspring in all subsequent generations are flies heterozygous for curly and for no-wing (most of the homozygous curly die), and a few flies homozygous for no-wing. This balanced stock of no-wing $\left(\frac{\text{curly}}{\text{no-wing}}\right)$ can always be used in out-crosses as though it were a stock pure for no-wing, because all the F_1 offspring that are not curly are known to have received the gene for no-wing. For example, if $\left(\frac{\text{curly}}{\text{no-wing}}\right)$ is crossed to lobe-^{2} females (lobe-^{2} is a dominant in chromosome II) all the lobe-^{2} not-curly offspring are heterozygous for lobe-^{2} and for no-wing. The amount of crossing-over between these two mutants is found by crossing such a female to a male that is $\left(\frac{\text{curly}}{\text{no-wing}}\right)$. The curly offspring are discarded, and the remaining flies fall into four classes as in a typical back-cross result. Thus: $\frac{L^2 \quad +}{+ \quad \text{no}}$ by $\frac{\text{Cy}}{\text{no}}$ = (1), curly (50 per cent); (2), lobe (non-cross-over); (3), wild type (cross-over); (4), no-wings (non-cross-over); (5), lobe no-wings (cross-over). The actual results were (I), 1581; (2), 725; (3), 130; (4), 362; (5), 67. The percentage of crossing-over is thus $\frac{197}{1284} \times 100 = 15.3$.

A second case has arisen, in which, according to genetic evidence, the right end of chromosome II has become transferred to chromosome III. In still another case a piece of chromosome II, containing the recessive gene speck, has been transferred to the left end of the X-chromosome.

There is another kind of genetic result, which may be interpreted as due to deficiency (a loss or inactivation of a section of a chromosome), of which the mutant notch is a typical case. Two new notches that are deficiencies, extensive enough to cover the locus of white, have appeared, and others not so extensive have been met with. A sex-linked character, minute-k, similar in behavior to notch has been found and similarly interpreted. The locus of minute-k is very close to that of miniature.

Further work is being done on the stock "double yellow" in which two X-chromosomes are present that are attached to each other and that consequently fail to separate at the reduction division. Occasionally these two X's break apart, and the separation does not always occur at the original point of union. This leads to the production of a number of unusual combinations of X's and fragments of X, giving complicated genetic results that are now being studied.

The unique behavior of the stock called bar (eye) has aroused a good deal of interest. As first observed by May, and more thoroughly studied by Zeleny, this dominant mutant reverts to normal eye with a frequency much greater than that of any other mutation in *Drosophila*. By arranging the experiment in such a way, that whenever crossing-over occurred near the bar locus it could be detected, it has been demonstrated that whenever a reversion occurs there is a cross-over in that region. Since crossing over occurs only in the female it was to be expected that bar-reversion would take place only in the female, and not in the male. Such is the case. It would be expected that this reversion would occur only late in the history of the germ-cells, since crossing-over is known to occur late. This also is found to be the case. An extreme allelomorph of bar, called by Zeleny ultra-bar, has been obtained from bar, and it has now been shown that in this event also crossing-over occurs within three units of the bar locus. These results can be explained if we represent the bar gene by B and two adjacent loci by M and N respectively. The homozygous bar female will be $\frac{M\ B\ N}{M'\ B\ N'}$. If we suppose that an unequal cross-over takes place in such a way as to produce M BB N′ and M′N, the former will represent ultra-bar, and the latter the reversion to normal. A confirmation of this assumption is found in Zeleny's data (collected for another purpose), namely, that $\frac{B}{B}$ (homozygous bar) has very nearly, if not quite, the same number of ommatidia as ultra-bar heterozygous for normal. These should be alike, by hypothesis, since each has two B's. Further tests of the hypothesis stated above are now under way.

In cooperation with E. G. Anderson, a study is being made of the crossing-over in the X-chromosome of the triploid (3n) female. Each of the three X-chromosomes is followed by means of five mutant loci. For example, one of the five points was marked by yellow in one X; by its wild-type allelomorph in a second X; and by scute, which gives no crossing-over with yellow, in the third. In addition, each X carried a recessive mutant gene crossveinless. Such a 3n female was outcrossed to a not-crossveinless male. All the crossveinless daughters of this outcross have received from the mother two X-chromosomes that have emerged from the same reduction division. A study of the characters representing the five marked points present in such females shows the origin of the different parts of each of the two X-chromosomes. It has been found that crossing-over may occur between all threeX-chromosomes simultaneously, since chromosomes emerge that are composed of parts taken from each of the three chromosomes that entered. The most frequent type of female is one that carries one chromosome that has not undergone crossing-over (and is a duplicate of one of the entering chromosomes) and another X that is composed of parts of the other two. A fairly frequent result is the emergence of two X's that are duplicates of each other for part of their length but not for the remaining part. This result indicates that each of the original chromosomes was in a two-strand stage when crossing-over occurred. In these 3n females crossing-over is relatively less frequent in the right end (from lozenge to bar) than it is in the normal (2n) female, while in the left it is relatively much more frequent. Thus, about 15 per cent of the emerging chromosomes have come from crossing-over between yellow and ruby, while the normal percentage is about 7. In the extreme left end crossing-over has been observed between yellow and scute, which had not been certainly detected in the diploid form. A more extended analysis of the data is expected to throw light on the details of the process of crossing-over.

In addition to the sex-linked mosaics, due to elimination of one of the two X-chromosomes of an egg at an early cleavage, a number of mosaics have appeared in which the two parts differ in autosomal characters. Most of these are interpreted as due to two separate nuclei in the original egg, each nucleus fertilized by a different sperm. One clear case of this sort is a mosaic from a back-cross in which the mother carried four recessives in one chromosome-III, and three others in the homologous chromosome. One side of the mosaic showed the three characters corresponding to one of the original chromosomes of the mother, and the other side showed three of the four characters of the other original chromosome (the fourth was lost by crossing-over). Another autosomal mosaic arose from a pair of flies that carried the recessive gene, vestigial, in one chromosome II, and the recessive gene, speck, in the other homologous chromosome. The mosaic was female and speck on one side and male and vestigial on the other side. Since there is no crossing-over in the male, the result shows that two sperm participated, one with an X and a chromosome-II with speck, and the other with Y and a chromosome II with vestigial. Presumably the egg had two nuclei, each of which after reduction had an X; one of the nuclei contained the second chromosome with speck, and the other nucleus the second chromosome with vestigial.

An interesting type of gene has been found that changes a mutant character back to wild-type. For example, three sex-linked characters (scute, tan, and hairy-winged) are changed to wild-type, each by a different suppressor in chromosome-III. In the case of hairy-wing, the suppressor produces certain other slight effects that are similar to those met with in previous cases of duplication. This suggests that this suppressor is a piece of chromosome that contains the normal allelomorph of the gene that is suppressed and that has been transferred to another location in the chromosome complex.

Further work on a certain stock of lethal-7, in which the so-called tumor fails to appear, has confirmed previous statements that in this stock the males that formerly showed the tumor, now die at an early stage before the tumor develops. A good deal of work has failed to show the nature of the change that has taken place in this stock. It is interesting to note that when this stock is outcrossed (using a lethal-7 female) some or many of the F_1 male larvæ show the tumor, which proves that the gene for the tumor production is still present.

Some extraordinarily low female ratios have appeared in certain lines of the double-yellow stock. As in other cases of change in sex-ratios of *Drosophila*, the effects are produced not by a change of females into males (or vice versa) but by the elimination of some of the individuals of one sex.

The work on *Drosophila simulans*, referred to in previous reports, has been continued. A useful new mutant gene has been found in each of the three genetically-known chromosomes. That in the X-chromosome is an isomorph of bobbed, which occupies, so far as we know, the extreme right-hand end of the melanogaster X. There are now 8 isomorphic genes known in the simulans X, including both the known ends of the melanogaster X. The new mutant gene in chromosome-III extends the map of that chromosome, making it at least 10 units (and probably 20 or more) longer than the corresponding *melanogaster* map. Studies of changes in crossing-over, due both to internal and to external causes, have been carried out with *D. simulans* during the year.

BOTANY.

Britton, N. L., and J. N. Rose, U. S. National Museum. *Studies of the Cactaceae.* (For previous reports see Year Books Nos. 11-16, 21.)

The work of the past year has been mainly devoted to the fourth and last volume of the Cactaceae, a monograph of the Cactus family upon which Doctors Britton and Rose have been engaged since 1912. This work has been based upon an exhaustive re-study of this large and difficult family after extensive field work in both North and South America and after growing most of the plants under glass either in Washington or in New York.

As treated in this monograph, the Cactus family is composed of 3 tribes. The first and second tribes are taken as units, but the third is composed of 8 subtribes. The number of genera recognized is 124 and the number of species is 1,235. The plant names, mostly synonyms, number more than 10,000. The colored plates have been made from paintings by the plant artist, M. E. Eaton.

The four volumes will contain 1,246 printed pages, 137 full-page plates, mostly in color, and more than 1,100 text-figures.

Livingston, Burton E., Johns Hopkins University, Baltimore, Maryland. *Studies upon the influence of solar radiation on the rate of transpirational water-loss from plants.*

These studies, begun a number of years ago at the Desert Laboratory, are part of a more general investigation aiming to develop methods and expressions by which the rate of transpirational water-loss from a plant may be understood in terms of the internal and external conditions that together constitute its control. The health and vigor of a plant depend in great measure on the water-content of its tissues, and the water-content is itself clearly a function of the rates of water-intake and water-loss. For this reason, among others, a knowledge of the conditional control of the transpiration rate must be essential to an understanding of the physiology of higher plants in general. Since the beginning made with the work reported in Publication No. 50 of the Institution, considerable progress has been made in these studies, to which many investigators have contributed. Several aspects of the general problem still require quantitative study, however, and the influence of solar radiation is one of these with which the writer has been specially engaged for several years.

The plant environment acts directly to influence the transpiration rate, only through those variable aerial and meteorological conditions that affect the rate of vaporization of water. These are the conditions that determine the rate of evaporation from a water-surface or the rate of diffusion of water-vapor. For convenience of approach, the aerial conditions here dealt with may be considered in two categories, the evaporating power of the air (the combined influences of air temperature, air humidity, and air movement) and the evaporating power of impinging radiation. The former group of conditions operates on ordinary plants at practically all times, by night as well as by day. The evaporating power of the air is generally positive but becomes negative sometimes, when plant tissues absorb water from moist air, or when dew is formed on plant surfaces. On the other hand, the influence of radiation is practically confined to the daylight hours, since solar radiation is the only sort that needs generally to be considered for plants growing in nature, and solar radiation is absent at night. It is always positive. At a later stage of advancement in plant physiology other natural sorts of radiation may need to be studied. Radiation from artificial sources may now be employed in experimental work, etc.

The evaporating power of the air and that of radiation have been measured in several ways, and the influences that they exert on plant transpiration have been studied with corresponding instrumental records, in experiments carried out at Tucson and at Baltimore. Progress has been made in the interpretation of records secured with the radio-atmometer, the black-bulb thermometer and a photographic-paper actinometer, with reference to the actual, observed influence of solar radiation on plant transpiration. Some comparisons have been made with records from a pyrheliometer.

Different kinds of plants differ in respect to their responses to solar radiation, as far as transpiration is concerned, and the same plant individual responds differently according to its stage of development and to the previous treatment to which it has been subjected. As would be expected, internal conditions, as well as other external conditions, are also markedly influential on the responses to radiation. Healthy plants, which are not approaching the wilting condition, generally respond to solar radiation relatively less than does the black atmometer sphere, and they generally respond relatively more than does the white atmometer sphere. But many details need to be considered.

One interesting feature brought out in these studies is this, that the influence of indirect solar radiation (radiation not received directly from the sun, but coming from the rest of the sky, from the earth, etc.) is not at all to be neglected in discussions of the influence of sunshine on plant transpiration. With no clouds or other shade intervening between sun and plant the direct component of solar radiation is of course predominant, but when the sun is obscured by cloud the indirect component may become the more influential of the two. With heavy cloud between sun and plant and with the rest of the sky largely occupied by light cloud masses which serve as reflectors, the radiation influence on the transpiration rate is still great in many cases. The two components may be studied separately.

It is hoped that these studies may eventually lead to the useful evaluation of the sunshine feature of climate as a drying agent acting on plants, etc., separating this important climatic character from the other drying influences. Such an advance ought to illuminate many problems of physiology, physiological ecology, agriculture, horticulture, forestry, and even hygiene and medicine. Also, the insight that is being gained along these lines of experimentation is helping us toward a better understanding of the water relations of plants and animals, and it is preparing for the time when it will be possible to carry out physiological experiments on higher plants under controlled conditions, so that some of the fundamental principles of plant control may eventually be established. Such experimentation is not yet possible and is greatly needed.

During the last two years I have been assisted at Tucson as well as at Baltimore, by Mr. J. D. Wilson, of the Johns Hopkins University. Much of the work here referred to has been accomplished at the Desert Laboratory, the facilities of which have been kindly placed at our disposal for long periods by the Director of that laboratory.

Osterhout, W. J. V., Harvard University, Cambridge, Massachusetts. *Continuation of investigations on permeability in cells.*

A problem important for the understanding of life processes is the nature of selective permeability. Protoplasm absorbs some substances very readily; others penetrate slowly or not at all. Since it is evident that the nature of the penetrating substances determines metabolism it is of importance to know which substances can enter. If we could ascertain this we might draw important conclusions regarding the nature of protoplasm, regarded as a physico-chemical system which allows certain substances to pass while excluding others.

The ideal method of attacking this problem is to place cells in a solution of the substance to be studied and after a suitable period of exposure to remove them and test their contents for the presence of the substance in question. To do this satisfactorily it is necessary to have large cells whose sap can be obtained without contamination. Hitherto such cells have not been employed. Experiments have been made upon small cells by a variety of methods which have not yielded concordant results, and therefore great confusion has arisen which may be avoided by the use of cells of appropriate size.

The writer has employed cells of a species of *Nitella*, which sometimes reach a length of 6 inches. After exposure to a suitable solution they are removed, carefully rinsed, and the sap obtained without contamination by cutting off one end of the cell and squeezing out the contents or by inserting a fine glass tube and removing the sap by suction. The sap is then tested for the presence of the substance which is in the external solution.

These experiments have demonstrated that, contrary to the views of many investigators, certain salts are able to penetrate protoplasm in its normal state. Further experiments are in progress which are designed to place the subject on a quantitative basis.

It is also important to study the giving out of substances by the cell. In the case of chlorides, for example, this can be easily accomplished by titrating the cell-sap. Chlorides are absorbed by *Nitella* from the water and stored within the cell, where the concentration may be 50 to 100 times as great as in the external solution. When the cell is injured the chlorides begin to diffuse out. By making frequent measurements a time curve may be obtained which is of interest. The mathematical analysis of the curve indicates that the process of injury, followed by death, follows a definite law which appears to be the same as that derived from measurements of the electrical conductivity of the cells.

An account of this has appeared in the Journal of General Physiology (July 1923).

CHEMISTRY.

Noyes, Arthur A., California Institute of Technology, Pasadena, California. *Researches upon (1) the properties of solutions in relation to the ionic theory; (2) free energies and reduction-potentials; (3) a system of qualitative analysis including the rare elements; (4) the structure of crystalline substances determined by X-rays; (5) the rates of chemical reactions; (6) theoretical thermodynamics.* (For previous reports see Year Books Nos. 2–21.)

1. Properties of Solutions in Relation to the Ionic Theory.

The anomalies in the properties of largely ionized substances have for many years been the subject of extended investigations, in which, through the grants to which this report relates, the Carnegie Institution has actively participated. These investigations are now rapidly coming to fuller fruition as the result of the mathematical development by Milner and by Debye and Hückel of a theory which shows that the deviation of the behavior of these substances from that of perfect solutes can be accounted for quantitatively (at least approximately) by evaluating the potential energy due to the electrical attraction between the positive and negative ions. Consequently, the researches during the past year have been directed to a simplification of the form of presentation of the theory, and to testing it with the aid of the already accumulated data. During the coming year the theory will be developed in forms specifically applicable to the different properties of fairly concentrated solutions, and it will be further tested in these directions.

To verify the theory adequately, new data relating to mixtures of salts of multivalent types have already been found necessary; and, as these data can be best derived from the solubilities of salts in the presence of one another, further experiments in this direction have been carried out with the aid of R. M. Bozorth and R. H. Dalton and R. Pomeroy.

2. Free Energies and Reduction-Potentials.

A report has been completed and published by D. F. Smith and Hubert K. Woods on a research concerning the free energy and heat of formation of lead monoxide from its elements. The work consisted in measurements at 25° and 45° of the electromotive force of the cell $Pb(s)+PbO(s)$, $Ba(OH)_2$ ($0.0766-0.2242$ m.), H_2 (1 atm.). Its free energy was found to be $-45{,}050$ calories and its heat of formation $-52{,}360$ calories. This free-energy value is in fair agreement with the value ($-45{,}460$ calories) derived from the new heat of formation and low-temperature heat-capacity measurements with the aid of the constant entropy principle (the so-called third law of thermodynamics), thus affording a further confirmation of that principle.

The free energy of another oxide, the type of compounds for which data are now most needed, has been determined, with the assistance of Mr. Reinhardt Schuhmann, who has studied antimony trioxide by measuring at 25° the electromotive force of cells of the type $Sb(s)+Sb_2O_3(s)$, $HClO_4$ ($0.1-1.0$ n.), H_2 (1 atm.). Its free energy at 25° was found to be $-148{,}600$ calories. Arsenic trioxide is now being investigated by the same method.

By determining the solubilities of antimony trioxide in perchloric-acid solutions of concentrations between 0.1 and 1.1 normal, and applying to the results the mass-action law, it was found that the antimony exists in these solutions mainly in the form of the univalent antimonyl ion (SbO^+); and from the solubilities and the electromotive forces the molal reduction-potential for the reaction $Sb(s)+H_2O+3\oplus=SbO^++2H^+$ was computed to be -0.212 ± 0.002 volts. These are the first experimental results that afford even an approximate measure of the antimony potential. The value obtained places it between hydrogen (± 0.0 volt) and bismuth (-0.30 volt) in the potential series, showing it to be more reducing than the latter element. In interpreting these results it was necessary to know the activity of the hydrogen-ion in the perchloric-acid solutions. This was determined by comparing the activity of this acid with the known activities of hydrochloric acid by measuring the electromotive force of cells of the type H_2 (1 atm.), $HClO_4$ (at c), HCl (at c), H_2 (1 atm.). For values of the concentration c between 0.1 and 1.1 normal such cells were found to have electromotive forces of only a few tenths of a millivolt. As this may well arise only from the liquid potential due to the difference in mobilities of the two anions, the conclusion is justified that the two acids have the same activity-coefficient at the same concentration.

All these results have been written up and sent to the Journal of the American Chemical Society for publication.

The line of research referred to in last year's report on the determination of the free energy of water-soluble compounds by measuring the electromotive force of cells containing them in contact with organic liquids has been continued by Mr. C. H. Prescott jr. Thus the free energy of solid sodium chloride has been derived from the electromotive force at 25° of the cell.

$$\text{Na in Hg, } NaCl(s) \text{ under } C_5H_{11}\,OH,\ HgCl(s)+Hg(l).$$

The value has thus been found to be $-90{,}800$ calories, in fair agreement with the value $-91{,}700$ calories obtained by Allmand and Polack from measurements with aqueous solutions.

3. A System of Qualitative Analysis including the Rare Elements.

During the past year, with the assistance of W. C. Bray and E. H. Swift, the work on the system of qualitative analysis, including all the metallic elements, has been continued. The plan of separation and detection of the elements of the groups precipitated by ammonium hydroxide and sulfide has been perfected and brought into form for publication. The rare elements gallium and indium have now been included in the scheme. As special items of analytical and preparative importance may be mentioned the discoveries that gallium, heretofore separated from associated elements with much difficulty, can be separated in a single operation from all of them except iron, by extracting it from a solution 6-normal in hydrochloric acid with ether; and that indium can be separated from rare-earths and other elements by precipitating it as the very characteristic bright-yellow sulfide from a 6-normal acetic-acid solution.

4. The Structure of Crystalline Substances determined by X-Rays.

The researches on the determination of the arrangement of atoms in the crystals of typical inorganic substances have been continued. Dr. R. G. Dickinson has worked out a structure for stannic iodide (SnI_4), which accounts satisfactorily for the X-ray data; this being the first inorganic substance which has been found to have a distinctly molecular structure. Dr. R. M. Bozorth has investigated the cubic crystals of arsenic trioxide and antimony trioxide, and has found them also to show molecular segregation, the molecular formulas being As_4O_6 and Sb_4O_6 as in the gaseous state. There has also been investigated the structure of KHF_2 (by Dr. Bozorth) and that of the hexagonal mineral molybdenite (by Dr. Dickinson and Mr. Linus Pauling). Mr. Pauling has studied single crystals of the intermetallic compound Mg_2Sn, and has found its structure to be like that of CaF_2; this being apparently the first complete determination of the structure of an intermetallic compound. The substance $NaCd_2$ was also investigated, but it was found to be surprisingly complicated.

A study by Dr. Dickinson of some radial streaks and anomalous spots observed in Laue photographs has led to the hypothesis that they are due to the existence in the crystal of a great number of small crystals individually perfect but with their axes slightly inclined to those of the main crystal, the number of individuals having a given inclination being smaller the greater the inclination.

5. Rates of Chemical Reactions.

Fundamental theoretical studies by Dr. R. C. Tolman, and experimental researches under his direction, have been initiated in this laboratory in an attempt to contribute to the principles underlying the rate of chemical reactions. These principles have long been one of the most important and baffling problems of theoretical chemistry. The laws of thermodynamics provide a theoretical basis for predicting what chemical reactions can take place and how far they will proceed before equilibrium is attained. Thermodynamics, however, is powerless to determine the rate at which the thermodynamically possible reactions will actually proceed. The final solution of the problems of chemical velocity will therefore be of extraordinary importance, since it will enable the chemist to predict not only the possible reactions in a given mixture of substances, but also the actual reactions which really do take place.

The effect of temperature on the rate of reaction, and the factors which determine the specific rate of reaction at any given temperature are questions which have not yet received adequate theoretical explanation. The most promising suggestion for their solution has been the radiation hypothesis of Perrin and W. M. C. Lewis, which attributes the activation of chemical molecules to the absorption of radiant energy from the black-body radiation corresponding to the temperature of the reacting mixture. Nevertheless, it has been shown definitely by the work of Daniels and Johnston on the decomposition of nitrogen pentoxide that light of the predicted frequency will not cause decomposition.

This failure, however, need not force us to complete abandonment of the radiation hypothesis. It was pointed out by Tolman in 1920 that the theory of Perrin and Lewis was seriously handicapped by the assumption that activation was produced by a single frequency, while it is known experimentally that photochemical reactions can often be produced by a wide range of frequencies; and he developed a more generalized theory of reaction.

Work in this laboratory for testing this theory has been undertaken with the help of Mr. Oliver R. Wulf; the reaction between bromine and cinnamic acid in carbon-tetrachloride solution being first investigated. The thermal reaction-rate has already been determined at 25° and 45°; and the reaction has been shown to proceed with a measurable photochemical rate in light of reasonable intensity. Apparatus is now being installed for the production of light of known frequencies, and for the measurement of light intensities for use with this reaction.

With the help of Mr. Ernest C. White work is also in progress on the initial rate of decomposition of nitrogen pentoxide. This is a matter of interest, since previous work has shown that, though the reaction is of the first order after it is once under way, the rate is very much slower in the absence of the decomposition-product nitrogen dioxide. The work has necessitated the design and construction of an elaborate all-glass colorimeter for measuring small concentrations of nitrogen dioxide. The apparatus has been completed and one preliminary run carried out.

A theoretical investigation of the temperature-coefficient of photochemical reaction rates has been published by Dr. Tolman. By the use of the methods and concepts of the quantum theory, a new and more illuminating derivation has been given of the same equation for temperature-coefficient as was originally derived on the basis of classical statistical mechanics. Existing data on temperature-coefficients have been successfully interpreted with the help of this equation. An equation for the change in temperature-coefficient with frequency was also derived, and successfully used in interpreting existing data; and the causes for apparent deviations from Einstein's hypothesis of photochemical equivalence were briefly discussed.

6. Theoretical Thermodynamics.

A theoretical study has been carried out by Professor R. C. Tolman and Mr. R. M. Badger on the entropy of diatomic gases and rotational heat-capacity. This has appeared in the Journal of the American Chemical Society. A direct mathematical method has been developed for determining the theoretical value of the constant in the equation for the entropy of a diatomic gas composed of molecules of the rigid dumb-bell model. Six different theories which have been proposed, all based on the first form of the quantum theory but involving different assumptions as to *a priori* probabilities and as to the lowest possible azimuthal quantum number, have been used to calculate the theoretical value of the constant, and the results have been compared with existing experimental data.

A theoretical study on rotational heat-capacity and half quantum numbers has also been made by R. C. Tolman. It is shown that the low-temperature data on the specific heat of hydrogen are not out of accord with the idea that the lowest possible azimuthal quantum number is one-half.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. *Continuation of exact investigation of atomic weights and other physico-chemical properties of elements and of simple compounds.* (For previous reports see Year Books Nos. 2–21.)

The following investigations have been in progress during the academic year, some of them continuations of work begun a year or more ago.

1. The Atomic Weight of Radioactive Lead.

Dr. Paul Putzeys, Belgium Research Fellow, investigated the atomic weight of radioactive lead obtained from the very interesting and important deposits of the Congo. He proved conclusively that lead obtained from these minerals consists largely of the uranium isotope of the metal, finding 206.2 as the atomic weight.

2. The Atomic Weight of Copper.

Mr. Arthur W. Phillips continued the study of the atomic weight of copper, using samples of copper from widely different localities and widely different geologic ages. He used a new method, the analysis of cupric chloride, and succeeded in proving that copper from the Lake Superior district has, within the limit of error, an atomic weight precisely equal to that of metal from the much more recent deposits in Chile.

3. The Compressibilities of Simple Salts.

Mr. Edouard P. R. Saerens, Belgium Research Fellow, continued the study of the compressibilities of simple salts. He discovered that rubidium and cæsium bromide behave in an anomalous fashion, changing their state of aggregation under comparatively low pressures, and he secured a wide variety of other interesting data. This research has reached a state in which the publication of the facts and of interesting relations between the several compressibilities is desirable, and may soon be undertaken.

4. The Properties of Liquid Water.

Mr. H. Marshall Chadwell continued the investigation of the physicochemical properties of water. To the data obtained in the preceding year, he added careful determinations of the lowering of the freezing points produced by various organic substances dissolved in water. A platinum resistance thermometer with all known refinements was used in this work. The object was to study the extent of the deviations from Raoult's Law exhibited by various substances. Some of the aspects of the work are almost ready for publication.

5. The Heats of Reaction of Slow Chemical Processes.

Mr. Hans C. Duus has taken up the investigation of this subject (begun by Mr. Oscar C. Bridgeman), has simplified and improved the apparatus, verifying within a reasonable limit of error the work of Mr. Bridgeman, and is now ready to carry the investigation much further in the coming year.

6. The Heats of Combustion of Carbon Compounds.

With the means now at command it is possible to improve the apparatus for determining these important quantities. Mr. Stewart S. Kurtz jr. has undertaken this task, and with an improved automatic adiabatic calorimeter is beginning the systematic revision of the data on heats of combustion, which furnish the chief basis of the thermo-chemistry of organic substances.

7. Specific Heats of Solutions, Heats of Neutralization, and Heats of Dilution.

Our recent work on these topics brought results so interesting and valuable as to indicate the desirability of continuing the investigation with other acids and alkalis. This work has been undertaken by Mr. Frank T. Gucker jr. He has constructed an elaborate twin calorimeter, operated and controlled electrically, by which the specific heats of solutions can probably be determined with hitherto unattainable accuracy. These fundamental data must be known accurately before heats of neutralization and heats of dilution can be evaluated. Mr. Gucker proposes to continue the investigation next year.

8. The Electrochemical Behavior of Barium Amalgams.

Mr. Paul A. Anderson has continued the study of the electrochemical behavior of barium amalgams, which offered unexpected difficulties. Further results have been obtained, but they are not yet quite conclusive. The chief difficulties seem now to have been mastered and it is hoped that Mr. Anderson in a few months next winter may be able to complete the investigation.

9. The Electrode Potential of Iron under Varying Conditions.

Mr. William T. Richards studied the effect of hydrogen-ion concentration and of powerful magnetic fields upon the electrode potential of metallic iron, both in the pure state and when saturated with occluded hydrogen. The investigation is completed and the results are almost ready for publication.

10. Theoretical Considerations.

Much time has been spent upon the study of the internal pressures of solids based upon the recent results concerning compressibilities. The outcome shows that in highly compact substances the volume-pressure relation is essentially hyperbolic and that the pressures existing in such substances are of a very high order of magnitude. The outcome had been used to calculate actual changes of volume which occur in atoms during chemical combination. Some of the results of these theoretical considerations have been correlated in a paper presented to the Royal Swedish Academy in Stockholm in December. An exhaustive discussion of the present status of atomic weights was presented for publication in the volume commemorating the dedication of the new Sterling Laboratory at Yale University. These papers have not yet appeared in print; but four other papers have been published since the last report.

Sherman, H. C., Columbia University, New York, N. Y. *Chemical investigation of the amylases and related enzymes.* (For previous reports see Year Books Nos. 11–21.)

During the year four papers, dealing with different aspects of our investigation of these enzymes, have been published in the Journal of the American Chemical Society. A fifth paper of more general scope, summarizing the evidence which we had obtained up to November 1922 in those phases of our work which bear directly upon the problem of the chemical nature of these enzymes, was read at the autumn meeting of the National Academy of Sciences and has since been published in its Proceedings.

The laboratory work of the year has been chiefly devoted to a further development of the experimental evidence that enzymic activity is influenced by amino acids in such a manner as to indicate that the enzyme is of protein nature or contains protein as an essential constituent, and to the verification of the hypothesis offered in last year's report to explain the differences shown by representative amino-acids of different types. To this end the inactivation of pancreatic amylase in water solution has been investigated more critically than hitherto and the two typical amino-acids, glycine and tryptophane, have been studied further with reference to their influence upon the enzyme, both in the absence and in the presence of the substance upon which it exerts its characteristic action.

When the enzyme (pancreatic amylase) in the form of high-grade commercial pancreatin was dissolved in pure water and held at a temperature of 10° C., it lost about one-sixth of its activity in 4 hours and about half in 24 hours. At 25° C., it lost nearly half of its activity in 2 hours and about two-thirds in 4 hours. At 40° C. the activity was entirely lost within an hour. When the same enzyme preparation was dissolved in water to which had been added sodium chloride and disodium phosphate in the proportions which we have regularly used in studies of the activity of this enzyme, the presence of these salts reduced the rate of inactivation to about one-sixth of that observed in their absence. In the presence of the salts about one-sixth of the enzyme activity was lost in 24 hours at 10° C. or in 2 hours at 25° C., and about two-thirds of the enzyme activity was lost in 24 hours at 25° C or in 2 hours at 40° C.

Although the rate of inactivation is thus greatly reduced by the presence of the salts it is still a very considerable factor with a high temperature coefficient, so that at 40° C. about half of the enzyme was destroyed or inactivated within an hour, even though the solution contained, as has previously been shown, optimum concentrations of chloride, phosphate, and hydrogen ions. All these statements regarding the inactivation of the enzyme in solution hold true for the loss both of its starch-splitting (amyloclastic) and of its sugar-forming (saccharogenic) activities. The parallelism in loss of these two activities indicates that these two phases in the digestion of starch are not due to two enzymes, but are two stages or phases in the action of one enzyme, and that the inactivation of this enzyme in solution is a process of actual destruction which is greatly accelerated by heat.

In view of the suggestion made by several writers that the vitamins be classified as enzymes, it is interesting to note that the results, which we have now obtained in the investigation of the heat destruction of the two groups of substances, show temperature coefficients so much higher for typical enzymes than for the water-soluble vitamins as definitely to place the enzymes and vitamins in different categories with respect to this important property. As explained in previous reports there is good reason to regard this destruction (or "deterioration") of the enzyme in solution as due to an hydrolysis of the enzyme molecule by the water in which it is dissolved, and the favorable influence of amino-acids as due to the checking of this destructive hydrolysis of the enzyme. All of our results without exception have been consistent with this view; but in one respect the different amino-acids studied have not all yielded exactly identical data. When tested in experiments of 30 minutes' duration at 40° C. in the presence of optimum concentrations of chloride, phosphate, and hydrogen ions, all of the amino-acids showed favorable influence upon the saccharogenic action of the enzyme, while upon the amyloclastic action a similarly favorable influence was observable in some cases but not in all.

Tryptophane is typical of the few amino-acids which did not show demonstrably favorable influence upon amyloclastic action within the half-hour of our usual determinations of amyloclastic power. This we interpreted as an indication that the tryptophane radicle is so bound in the enzyme molecule that its liberation occurs only at a relatively advanced stage in the hydrolytic destruction of the enzyme, and hence the addition of tryptophane to the solution in which the enzyme is acting would more readily show its effect in the case of the saccharogenic action which has to do with the later phase of the enzyme's activity. According to this hypothesis, then, a favorable effect of tryptophane upon amyloclastic action might also be found if tests be made under conditions such as to induce a more extensive destructive hydrolysis of the enzyme, either by exposing the enzyme to the action of the warm water for a longer time or at a higher temperature. This we have now investigated and found to be true. Both when the enzyme is held in water for a longer time at 40°, and when it is so exposed for even a short time at 50°, the favorable influence of the tryptophane upon the amyloclastic as well as the saccharogenic activity of the enzyme becomes clearly demonstrable.

In a parallel series of experiments, carried out during the year in this laboratory without financial aid from the Institution, but in close coordination with its work, we have found that the rate of destruction of pancreatic amylase is 30 times as great at 50° as at 40°.

Hence we had reason to expect that if our theory is correct the favorable influence of the tryptophane in conserving the enzyme would be measurable even in relatively short periods of time at the higher temperature, and in fact we found that when thus tested in the solution of a highly purified pancreatic amylase the tryptophane reduced by about one-third the loss of activity shown by the enzyme when held in solution at 50° C. for 15 minutes.

In connection with these studies we have investigated the optimum hydrogen-ion concentration for the activity of pancreatic amylase at temperatures ranging from 30° to 60°, and for digestion periods from half an hour to 2 hours, and have found that throughout this entire range of time and temperature the greatest activity, both amyloclastic and saccharogenic, is shown at the optimum which we had previously established for digestions of 30 minutes at 40° (pH = 6.7 to 7.2). In order to determine whether this is a relationship of general application, a similar study of malt amylase is now being made.

The work of the past year, together with that of the years preceding, has therefore thrown light upon the chemical nature of pancreatic amylase (and to a less extent upon that of malt amylase and of pancreatic protease also) from three different angles: (1) the preparation of the enzymes in the form of highly purified products and the direct analysis of these products with reference to their ultimate and proximate composition, physical properties, and behavior toward chemical tests; (2) the comparative effects of different antiseptics, those characterized by their chemical action upon proteins being found very much more destructive than those of the lipoid-dissolving type; (3) the destructive action of warm water upon the enzyme and the effects of amino-acids in retarding this destruction. The data of these three lines of evidence are entirely consistent and all point to the protein nature of the enzyme.

This work upon the chemical nature of the amylases and related enzymes is now being extended; and studies of their enzymic activity and physicochemical behavior, planned in the light of newer knowledge of their chemical nature which we have gained through the work of the past few years, are now being undertaken.

The efficient collaboration of those who have shared in these investigations, whether as research assistants or volunteers, is gratefully acknowledged.

Smith, Edgar F., University of Pennsylvania, Philadelphia, Pennsylvania. *Continuation of the study of the sodium tungstates.* (For previous reports see Year Books No. 16, 17, 21.)

The study of the sodium tungstates has been continued during the year. One paper has been published. In it the methods for preparing the 4 : 10 salt have been carefully reviewed and a new method for its preparation described.

Many new properties of the 4 : 10 salt have been brought to light. In the unpublished portion of this study effort has been directed to the preparation of di- and tri-tungstates in the wet way, without success, but there has come to light this fact, namely, that the addition of tungstic acid to normal sodium tungstate always, no matter how small its amount, gives rise to the formation of 5 : 12 or 4 : 10 sodium tungstates. Such being the case, the thought arose that probably 5 : 12 and 4 : 10 could be synthesized. This has been accomplished with excellent results; and further, the hydrolysis of the 5 : 12 and 4 : 10 sodium salts has been discovered to occur in proportions corresponding to those by which the 5 : 12 and 4 : 10 salts were synthesized.

Again, in hydrolyzing the 5 : 12 salt, for example, it was found that the normal tungstic acid present in this salt could be quantitatively precipitated by an excess of zinc sulphate, leaving unprecipitated the meta-zinc tungstate. The values obtained in this way for the normal tungstate and the meta-tungstate correspond with the ratios which were obtained in the synthetic process. Hence, in the case of the 5 : 12 salt its representations may be expressed by the union of 8 molecules of normal sodium tungstate with 7 molecules of sodium meta-tungstate. In other words, the whole conduct of this salt and the 4 : 10 salt point to them as products of the union of normal sodium tungstate, which is very basic with meta-sodium tungstate, which is extremely acid in its reaction.

The de-hydration of these salts and many other lines of work with them, such as the study of various metallic salts and double salts, is under way.

CLIMATOLOGY.

Antevs, Ernst, University of Stockholm, Sweden. *The big tree as a climatic measure.*

In the spring of 1923 the writer, on the request of President Merriam, undertook a revision of Dr. Ellsworth Huntington's study of the big trees, *Sequoia washingtoniana,* as a climatic measure. Of the large material, kindly placed at the writer's disposal by Dr. Huntington, trees growing on more or less dry ridges, high above water, were selected on one side, and on the other side trees living in the moist bottoms of the valleys in or close by water. The trees of these two groups were treated separately. The selected measurements belonging to the same group of age were added and curves plotted from the totals. These curves were corrected after a new graphic method for growth-variations depending on age and flaring. The obtained figures were tabulated. The parts of the curves between 1301 and 2100 years of age were added separately, also the parts younger than 1301 years separately. Parts older than 2100 years were not used. The sums obtained were divided by the totals of the measurements and the results were plotted in curves which record as accurately as the material permits the climatic fluctuations which have influenced the growth.

By adding the totals of the two groups and dividing by the sum of the totals of the measurements, a curve of the whole "dry" and "moist" material was secured. Finally a curve was obtained in a somewhat different way.

From 1001 A.D. to 1900 A.D. it is based upon all of Huntington's material. Only the age stage from 1301 to 2100 years was used and only correction for flaring was applied. The part from 1001 B.C. to 1000 A.D. was composed of all of Huntington's material belonging to the groups 20 to 31. It was corrected by groups in the usual way.

The variations of the final curves, corrected for variations depending on flaring and on different rates of growth according to age, may largely be due to changes in climate and weather, for influences caused by shading, liberation, abundant seed production, defoliation or other injury caused by insects, fire, frost, wind, etc., are essentially eliminated by the great number of measurements from different regions and by omission of trees showing such effects. A comparison of these curves and Huntington's curve, obtained in a different way, reveals the remarkable fact that they all agree in those parts that are computed from a very large amount of material. Thus, the correspondence is particularly good, partly even detailed, since 800 A.D. All the curves show maxima in the beginning of the tenth and eleventh centuries, during the fourteenth century, and since about 1550. They have minima in the latter parts of the tenth and twelfth centuries and about 1300 and 1500. The agreement evidently is real and almost surely of climatic origin. Thus, the growth of the big trees, allowance being made for effects of casualties, etc., is essentially determined by a combination of factors, and the rôle played by each factor is subordinate and varying.

The chief climatic factors influencing the growth appear to be precipitation, temperature, and sun radiation. The relative rôle of each factor is dependent on the time for its effect, upon other factors, upon internal conditions in the tree, etc. Thus, growth can primarily follow now this, now that factor. No direct study of the relationship was ever made, so that not even the general laws are known.

In the case of the big tree the importance of the individual factors is much more difficult to estimate as data of temperature are entirely wanting. However, it appears to be certain that the sequoia curves do not specially record precipitation; high parts in the curves might directly or indirectly be connected with periods of heavy rainfall and low parts with scanty rainfall, but it can not be concluded that all high and low parts were so. In this connection it is worth mentioning that the tree-growth maximum during the fourteenth century coincided with an exceptional spottedness of the sun and with the climatic stress of which there are abundant historical records in the Old World, and which particularly expressed itself in unusually cold winters, cold rainy summers, and devastating storms. Accordingly, before satisfactory interpretation of the sequoia curves and conclusions from them regarding the climate of the past and regarding the relationship between variations of growth and fluctuations of lakes and changes of human culture in the Southwest can be made, it is necessary to have data on temperature, better knowledge of the relation between precipitation and growth of sequoia trees in dry situations, and general knowledge of the rôle of the sun radiation for growth.

Besides being of climatological interest the sequoia curve is of importance as eventually affording a possibility to extend the Swedish post-glacial geochronology up to present time. This chronology, worked out—not yet published—by Ragnar Lidén in the valley of the River Ångermanälven (63° N.) is based upon annually laminated silty clays deposited in fiords of the Gulf of Bothnia ever since the disappearance of the last ice sheet. The annual deposit consists of two thin layers, the upper dark gray zone of which, the equivalent of the winter layer in the glacial varve clay, is essentially deposited in connection with the flood of the rivers during the melting of the snow in spring. By upheaval of land amounting to about 900 feet the clays have been gradually raised above sea-level and trenched by the rivers. Those from the last hundreds of years, are not yet accessible, and Lidén has had to estimate the length of time that has elapsed since the formation of the youngest measured varve or annual layer.

This gap in the record might be bridged by help of the sequoia curve, for it seems likely that it will show certain correspondence to the sedimentation curve in Norrland. The climatic stress during the fourteenth century. so distinctly recorded in the sequoia curve, is probably also recorded in the clay deposition. If this prove to be the case, and also other marked fluctuations in the tree curve will be found in the clay curve, a connection may be made with high degree of probability, and the length of the post-glacial time, which amounts to about 8,500 years, exactly determined.

Huntington, Ellsworth, Yale University, New Haven, Connecticut. *The big trees as a climatic yard-stick.* (For previous reports see Year Books 9, 10, 11, 14, 15.)

The purpose of this investigation was to test the supposed relationship between rainfall and the growth of the Big Trees by means of correlative coefficients. It was found that while there is a positive and significant correlation between tree-growth and the rainfall at Sacramento, the nearest station with a long record, there is much stronger correlation with the rainfall at Baor, a station on the Southern Pacific railroad at about the altitude of the trees. The strongest correlation is between the trees and the rainfall at Jerusalem. Farther west in the Mediterranean this dies out. A comparison of the rainfall at Bora with that of stations in all parts of the United States indicates a decided contrast between the southwestern and southeastern States, the rainfall tending to decrease in the southwest when it increases in the southeast and vice versa. The general conclusion is that the Big Trees, when studied by the method of correlative coefficients, show that they can properly be used as a climatic yardstick for certain areas in various parts of the world, but not for other intervening areas.

Another phase of the present study indicates that the rainfall of the second or third year previous to the growth of the trees has the greatest effect on growth. Where trees grow in moist places the rainfall for as long as ten years has some effect.

ECOLOGY.

Clements, F. E., Tucson, Arizona. *Associate in Ecology.* (For previous reports see Year Books Nos. 16–21.)

The experimental work of the summer has again been carried on, largely at the Alpine Laboratory, from June 1 to October 1, and further investigations of the volume and composition of soil-air have been made during the autumn and winter. The studies at Tucson have been continued at both the Desert Laboratory and the Santa Rita Range Reserve, the chief attention being paid to the water cycle, the quadrat method, and the climatic control of growth and regeneration in grassland. Experimental and statistical studies of the Madieæ and *Haplopappus* have been prosecuted at the University of California, together with an ecological inquiry into the development and modification of laticiferous tissues. The two major transects for experimental evolution, the Sierran and the Petran, have been extended and the transplant areas and gardens considerably augmented. Root studies have been further developed at the University of Nebraska, as well as studies in root behavior under irrigation at Greeley, Colorado. The field stations from eastern Nebraska through Kansas into Colorado have been kept up, and a special series of installations have been made in order to determine the transpiration of different types of vegetation and its possible relation to rainfall.

In addition to numerous short trips throughout southern Arizona during the winter, which were devoted primarily to the origin and development of the desert-plains grassland, a large portion of the West was again covered by motor. The first journey traversed the Colorado and Mohave Deserts in early spring, and several days were devoted to making a complete circuit of Death Valley, the major objectives being the reconstruction of the original grasslands of these deserts and the climatic significance of the bad lands and their sediments. During the spring and early summer frequent trips were made along the coast and the mountain ranges of southern and central California, followed by an expedition through the redwood belt and the Coastal forest of northern California, Oregon, and Washington. At Mount Rainier especial attention was given to the alpine vegetation, to snow parks near timber-line, and to natural parks in the three forest climaxes. A careful scrutiny was made of the ecotones between the Coastal forest, sagebrush savannah, Transition forest, and bunch-grass association on the journey through eastern Washington and Oregon, Idaho, Utah, and Wyoming. The origin and relationships of the three eastern grassland associations, mixed, true, and subclimax prairie, were further studied from eastern Colorado through Nebraska to eastern Kansas. Finally, the contact between grassland and forest or scrub was again traced from Kansas through Oklahoma to the coastal prairie of Texas and thence westward through New Mexico and Arizona to Tucson.

Factor stations, with the full equipment of physical instruments and often with phytometers as well, have been maintained at the Alpine Laboratory, at Greeley, on the Santa Rita Range Reserve near Tucson, and through the series of grassland stations. At the first, these have been employed in the further analysis of phytometers as habitat measures, while in the last a single battery was utilized successively at the three stations in the endeavor to compensate in some measure for differences in altitude and the corresponding lag in the season.

The Phytometer Method, by F. E. Clements and G. W. Goldsmith.

Sunflower phytometers have been carried through the season in three habitats at the Alpine Laboratory, viz, full sunlight, partial shade, and full shade. The initial rates of transpiration per leaf area were determined for a large number of plants under identical conditions and the batteries for the stations selected so as to have similar transpiration rates. Special containers were devised, shaped as two truncated cones base to base and equipped with two half-inch tubes, one reaching nearly to the bottom, the other just penetrating the metal of the top, in order to allow both top and bottom watering and also to permit the soil atmosphere to be replaced by atmospheric air. The conical form was chosen because of the reduced area left for sealing and also because this form permits firming the soil with the least possible interference. The wax-cloth seal was employed, with the addition of a plastocene collar around the plant-stems to prevent injury from hot wax of high melting-point. Each battery consisted of 10 plants, 2 blanks to check the efficiency of the seal, and 2 free check plants. The physical instruments installed in each station showed the shade station to have greatly reduced light, temperature, wind, and evaporation values and a very constant soil temperature, in comparison with those obtained at the sun station. The partial shade gave values somewhat nearer those of the shade than of the sun station.

The transpiration results from the phytometers yielded values for these habitats which represented the summation of the factors measured partially by the instruments. As to growth, the plants in partial shade exhibited greater height, smaller stem diameter, and thinner leaves than those of the sun station; plants grown at the shade station were much smaller, both in stem diameter and leaf area, than those at either of the other stations and also differed conspicuously in the succulence of the stems and leaves. Microscopic examination of the leaves showed a very slight palisade development, the mesophyll being chiefly sponge-tissue and wider than that of the leaves developed in partial shade. Stomatal movement, pigment content, water conduction, and gas exchange in the stems were also determined at each station.

Short-period phytometers were also employed to measure the differences between habitats in terms of single functions, such as transpiration. These have the advantage of being much simpler to install and attend and of giving much more accurate results, as smaller containers can be used and more uniform conditions selected, as to time especially. Moreover, they are much less subject to a wide variety of accidents, and the sealed plants can be maintained for periods of a few hours to several days in practically normal root condition. Such batteries have been used with marked success for several days in readings varying from 1 to 4 hours, for day and night, and for 24 hours, the conditions measured being light, slope-exposure, angle of slope, radiation and reflection from different soils, and the altitude complex. The results of the work of the four summers are now being prepared for publication.

The final results obtained by the use of phytometers in the analysis of marked differences in the physical factors and vegetation of north and south slopes are indicated in the following section. The methods and results pertaining to other forms of phytometers, namely, the sod core used for transpiration in natural grassland and the cut quadrat employed for the measurement of seasonal growth, are discussed briefly in later sections.

Slope-Exposure Studies, by F. E. Clements and Dolly Lutjeharms.

The investigation of the striking differences in the vegetation of the north and south slopes of Engelmann Canyon has been completed, and the results are in process of being published in full, in addition to being abstracted in the forthcoming paper on the phytometer method.

The data for the physical factors show that these are much more intense on the south-facing slope than upon the opposite one. Air temperature and humidity exhibit the smallest differences between the two slopes, 2 and 6 per cent, respectively, while light intensity, evaporating power of the air, and wind velocity are each 50 per cent greater on the south slope-exposure. Soil temperature presents more variation between the slopes than does air temperature—32 per cent as contrasted with 2 per cent. In spite of the fact that the rainfall is practically uniform, the soil moisture at all depths on the south slope-exposure is approximately one-third less.

The phytometers responded directly to the surrounding conditions, and growth increment, with the exception of stem height, was greater on the south exposure. These plants, with 14 per cent more leaf area, 10 per cent greater stem diameter, and 25 per cent less stem height, were able to produce 75 per cent more dry matter. The lesser stem height is believed to be a direct result of the heavy transpiration, which was 82 per cent greater on the south exposure.

It is thus apparent that the factors which favor high transpiration, namely, high wind velocity, high evaporating power of the air, and high soil temperature, likewise favor high photosynthetic activity. Light intensity is also an important factor in the production of dry matter. Judging from the responses of the phytometers, high wind velocity, high evaporating power of the air, and low holard, especially the latter, seem to determine the open aspect of the south slope-exposure. On the other hand, the denser, more wooded character of the north slope is due to the reverse conditions—low wind velocity, low evaporating power of the air, and high holard.

The Water Cycle in Plants, by F. E. Clements and J. V. G. Loftfield.

The emphasis during the summer has been placed on the plasmolysis method for determining cell-sap concentrations. Although this has been used by others almost wholly with plants having colored sap, it has been found possible to employ it with reasonable certainty in all the plants studied. Most of the work has been done with a selected strain of sunflower, grown at the Alpine Laboratory in three factor stations, namely, in the open, in partial shade, and in dense shade. A number of 24-hour series were made with these plants, in which the stomatal opening and guard-cell and epidermal-cell concentrations were measured at 3-hour intervals. Although both Iljin and Wiggans found the concentration of epidermal-cell sap to remain constant while that of the guard-cells varied, this did not prove to be the case in sunflower or in any of the other plants studied. At times the concentration of the epidermal cells was very nearly constant, more often it was found to vary appreciably, and in a few instances it varied more than in the guard-cells. Usually, the concentration of the epidermal-cell sap rose after 10 a. m. and continued to do so until after midnight, when it would start to fall. The concentration within the guard cells rose sharply after daybreak, when stomatal opening started, and showed the greatest departure from that of the epidermal cells just before maximum opening occurred. After this time, the concentrations within the two sets of cells distinctly approached each other as a rule, although the stomata might remain completely open. As the stomata began to close, the concentration of the guard-cells dropped and became less than that of the epidermal cells for a time. After closure was completed, the two concentrations again approached and soon became identical, equilibrium being established. The average concentration of the epidermal-cell sap at the three stations varied considerably. Work is also in process to determine the changes in the sap of the chlorenchyma-cells during a 24-hour period, as well as the rate of permeability to the hexoses and sucrose.

An attempt was made to correlate conduction, as measured by a modification of Farmer's method, with transpiration and leaf area. Previous work had shown that no definite relation existed between stem diameter and conduction, but a number of interesting relations were found in regard to the region at which the stem was selected. Such a relation seemed also to exist between the number of leaves and the amount of conduction. It was often found that it made but little difference in the rate whether the entire stem was used, the water then escaping from the cut ends of the petioles, or a short section from the base. Thus, the basal portion of the stem seemed to determine the rate of conduction. This, however, varied in most cases with the number of active or mature leaves, as well as with the habitat from which it had been taken. The stems of the sunflowers from the three factor stations were used in the determination of the ratio between leaf area and the rate of conduction. Great variation occurred at all times, and this may possibly be attributed to experimental difficulties in using soft, weak stems, but in consequence the results are not entirely conclusive. Extreme variation was exceptional, however, and in most instances the results corresponded closely. The sun-station plants (the extremes not included) gave a ratio of 0.47 c.c. (±.005) per hour per square decimeter of leaf, partial-shade station plants 0.87 c.c. (±.02), and shade-station plants 0.43 c.c. (±.005). The differences found at the various stations are not necessarily explainable by the average transpiration rates but apparently by the extreme rates of transpiration.

Studies in Aeration, by F. E. Clements and G. W. Goldsmith.

The apparatus for the determination of the quantity and quality of soil-air has been improved so as to simplify field manipulation and increase the accuracy of the determinations. Readings made during the dry winter season on the prairies near Colorado Springs indicate that moisture rather than temperature is the factor limiting the activities of soil micro-organisms in this region. During prolonged dry periods the air-content of the soil approaches atmospheric air in composition, but when these droughts are broken by a rain the free oxygen of the soil-air is rapidly reduced and the carbon dioxid increased as far as the moisture penetrates. The deeper layers of the soil, which are uniformly dry throughout the season in this region, maintain a winter atmosphere similar to the free air. Since root activity is presumably slight during the winter, atmospheric changes following the addition of moisture are probably due to the activities of the micro-fauna and flora of the soil. The dominant plants of this region must therefore be able to maintain root absorption in reduced oxygen pressures and increased carbon-dioxid tensions, and this capacity may be of much importance in the growth and competition relations of the dominants and subdominants.

Controlled field studies have been undertaken to determine whether the percentage composition of the soil-air alters the rate of root absorption or the amount of moisture remaining in the soil at the time of temporary or permanent wilting and whether this varies markedly in plants typical of the prairie formation.

Physical Properties of the Sap of Engelmann Spruce, by G. W. Goldsmith and J. H. C. Smith.

Picea englemanni occurs from the base of the mountains to timberline in the Pike's Peak region, although the best development is found near 9,000-feet elevation. Since the time and rate of growth differ at the various elevations, a study was undertaken of the sap expressed from the leaves. Temperatures attainable by the use of salt-ice mixtures were not low enough to produce permeability in the treated leaves, since comparable temperatures commonly occur during the winter in the various habitats, and consequently treatment with chloroform vapor for 48 hours at zero was employed to render the tissue permeable. The sap-content, freezing-point, acidity, density, refractive index, optical rotation, and titration curve were determined for each of four samples of leaves taken from four stations, namely, Shelter Rock at about 7,000-feet elevation, Half Way at 9,000 feet, Timberline at about 12,500 feet, and Krumholz at practically the latter elevation. The leaves were selected from similar positions on the trees and were the youngest present in every case, and hence they were never more than one year old. They were removed from the twigs and immediately placed in the glass containers in which they received the chloroform treatment.

The sap-content of the leaves varied with the season and elevation, being steadily reduced in the Krumholz during the winter, often reaching extreme desiccation in March and April. During the same period the sap-content at the other stations suffered a much smaller reduction. Desiccation was accompanied by increased acidity. There was little optical rotation at any period. The titration curves show a high buffer action at all seasons and characteristic dissociation curves as the young leaves age and become frost resistant.

Experimental Pollination, by F. E. Clements and Frances Long.

During the present season the emphasis has been placed upon the relations between nocturnal insects and flowers and upon constancy, especially at the end of the season. *Hyloicus separatus* and *Protoparce maculata* were the usual visitors for nectar to *Anogra albicaulis* and *Pachylophus cæspitosus*, and frequently also to *Gilia aggregata*, a pink-flowered species. *Sphecodes* came regularly at dusk and collected pollen alone, working with great industry. The small diptera that haunt *Pachylophus* hover in the air about the flowers until the stigmas push through the tip of the corolla, when they land and move to the anthers as the flowers open, covering them in a black swarm.

Constancy at the end of the season varied with the species and individuals, but especially with the weather. On the first day after a protracted period of rain or after snow, *Bombus juxtus* visited flowers of all the genera still in bloom, while on bright days the visits were usually confined to either *Geranium* or *Aster*. A number of individuals were marked with colors and the flight and visits followed for considerable periods. *Bombus bifarius* went to 627 florets on 52 heads of *Aster* during one flight, and then returned repeatedly within an hour to visit the same flowers. Removing or covering the ray-florets produced little effect, but with a single exception all the bees were deceived when the disk was covered with a circle of green leaf or paper.

The value of changes of color during anthesis in guiding bees to the flowers with abundant nectar is supported by studies of *Lotus* and *Lupinus*. One marked individual of *Bombus californicus* paid 134 visits to the fresh yellow flowers of *Lotus glaber*, 4 to those turning pale orange, and none to the old flowers which become orange-red. Another individual went to 250 fresh blue-purple flowers of *Lupinus affinis*, without once heeding the older ones which were changing in color.

Translocation and Storage in Autumn, by F. E. Clements, Frances Long, and J. V. G. Loftfield.

In connection with the investigation of the life-history of the vegetative plant, as well as that of the flower, studies have been made on photosynthesis, translocation, and storage in a number of perennial herbs blossoming through September, while several vernal and estival species were employed as checks. Attention was directed chiefly to the activity of the stomata, the presence of starch-grains in the guard-cells and mesophyll, and storage in stem, roots, and rhizome, with especial reference to the shoots of the season and the buds for the following year. Examinations were made at successive intervals after the stomata were first found not to be opening in mid-day, while blooming continued normally, and these were timed to take into account the effect of minimum night temperatures, snow, and returning sunshine and warmth. The effect of shade was also included. Practically all the species taken in full sunlight on the second day after a snow that persisted for two days showed no starch in the guard-cells or in the mesophyll. After a week of daily sunshine, all of these again gave starch in the guard-cells and most of them in the mesophyll also. Under unfavorable conditions, such as snow or cold nights, the sun forms of *Smilacina stellata* and *Geranium cæspitosum* contained no starch in the leaves, while the protected shade ecads continued to show it in both guard-cells and mesophyll. As would be expected, the behavior of the stomata was in agreement with that of the chloroplasts, complete closure persisting during periods of snow or cold nights, and mid-day opening being slowly resumed in some measure after successive days of sunshine. The species differed much as to storage in stem, rhizome, and roots, the vernal ones usually exhibiting the most.

Factors involved in Opening and Closing of Flowers, by G. W. Goldsmith.

Further work with *Mentzelia nuda*, which regularly opens in the late afternoon and closes during the early night, as does *Mentzelia multiflora*, indicates that the opening of the flowers is nearly independent of temperatures ranging from 18° to 30°, but that the younger flowers may be caused to open by a sudden and considerable decrease in the amount of light reaching the plant. The work is being continued in order to determine whether the light is effective through the thermal effect on the tissue, and hence the turgor, or whether some other causal mechanism is involved. As in the case of *Mentzelia multiflora* previously reported, cutting the branch results in a loss of floral movement for 24 hours or more, the flowers remaining in the condition in which they were when removed from the plant. A life-history study of the flower shows that the sepals lose their power of movement first, followed by the petals and stamens. In *Pachylophus cæspitosus* and *Aster bigelovi*, on the contrary, the movements are induced by temperature changes, cold opening the one and closing the other, while heat has the opposite effect. In both, the effect is readily reversible, in *Aster* especially it being possible to open and close the flowers repeatedly and at all times of day. The response in the latter bears a definite relation to the age of the head and rays as shown by the number and condition of the disk-flowers that are in bloom. Young heads close or open completely in a few minutes, older ones more slowly, and old ones imperfectly after an hour or more, if at all.

Experimental Taxonomy, by F. E. Clements, H. M. Hall, and David Mason.

A series of long-time experiments, designed to test the nature of characters used in the classification and description of plants, was initiated in 1919, and additions have been made in each succeeding year. During 1923 all transplants previously made in this study were carefully curated and their condition recorded. Several hundred new reciprocal and variation transplants were made, but especial attention was given to the formation of a series of adaptation gardens where species may be grown under as large a variety of conditions as possible. For example, at 4,500-feet altitude in the Sierra Nevada of California, small tracts were prepared to give the following range of conditions: dry sun, wet sun, dry shade, wet shade, and half shade with the addition of nitrogenous fertilizer. In a series at the Alpine Laboratory the habitat factors have been measured for a number of years and similar installations will be made from time to time in the other series. Fifty species of plants were selected, mostly herbaceous perennials, and uniform representatives of each were moved into all of the prepared areas. Whenever possible, as in the case of species with root-stocks, the propagules were all taken from a single individual. Since the entire series was repeated in a second set of gardens, the total number of plants moved at this station was 500. A similar series of experiments was inaugurated at 9,000-feet altitude in the same range, but here only three sets of conditions were provided. Fifty species were moved in duplicate, making 300 transplants at this station.

In order to test the effect, upon plant structures, of factors connected with altitude, and in order also to determine the limits of ecesis, some attention has been given to the transfer of sods and rooted plants to different elevations. About 50 alpine and subalpine species of the Sierra Nevada were transferred to a tract at 9,000-feet altitude, many of them as sods with at least one cubic foot of soil; 110 species were similarly transplanted to 4,500-feet altitude; and about 30 species were taken to sea-level. Transplants in the opposite direction, in connection with this experiment, numbered about 75, some of which came from the sagebrush association of eastern California. A considerable number of alpine sods have been moved into the montane zone at the Alpine Laboratory, and 3-5 individuals of characteristic dominants and subdominants of the plains grassland have also been planted in the same climax. The total number of transplants now in position and growing is 2,267, of which 607 are in Colorado and 1,660 in California. There are 499 species and subdivisions of species represented in the experiments, 237 of these being Rocky Mountain forms and 262 Californian.

Experimental Mycology, by F. E. Clements and E. S. Clements.

A comprehensive study of the life-history and adaptation of the fungi, including the lichens, has been begun by means of experimental and statistical methods, similar in a general way to those already developed for flowering plants. This has been organized around the transplant method, but life-history, statistics, and the quadrat method all play essential parts in the plan. As a preliminary step, individuals and groups of a considerable number of genera of fungi and lichen-fungi have been staked in different situations for the purpose of tracing the life-history and the seasonal and habitat variations. Representative individuals of these have been moved to a transplant transect, which affords three different minor habitats. Each species has been transferred into each of these, those of the same genus, family, or order being placed together for the sake of comparative values. Changes of soil and substratum have also been effected to further test the adaptability of the lichens especially. Reciprocal transfers of the latter have also been made between the montane and the alpine climaxes. In connection with the quadrat project, permanent quadrats have been located in these climaxes and chartered to scale by means of the camera, and denuded ones have been installed to show lichen reestablishment and growth. Finally, an inquiry has been initiated with respect to the evolution and migration of typical boreal fungi in the hope of obtaining additional light on the phylogeny and relationship of genera and species and of discriminating more closely between species and their variads.

Phylogenetic Method in Taxonomy, by F. E. Clements and H. M. Hall.

The first attempt to introduce experimental and quantitative methods into taxonomy has been made in the treatment of three important genera of North American plants, namely, *Artemisia*, *Chrysothamnus*, and *Atriplex*, which has been published in the form of a monograph during the year. Since experimental methods, to be conclusive, must extend over a long period of time, these are still in progress on the genera just named, but the results already secured warrant their publication for their intrinsic value as well as for a guide to others who wish to do objective work in this field. Particular emphasis is also placed in this volume upon the importance of field studies, of an improved nomenclature, and of the more readily intelligible expression of results, while the absolute adherence to phylogeny as the basis of classification is especially urged.

The following results were obtained in applying these methods to the North American forms of the selected genera: The 125 "species" of *Artemisia* of certain authors are grouped into 29 major species, 29 subspecies, and 120 minor variations; the 88 described forms of *Chrysothamnus* are brought into 12 species, 40 subspecies, and 44 minor variations; the forms of *Atriplex*, comprising as many as 103 species, according to a recent authority, are grouped into 47 species, 37 subspecies, and 70 minor variations. The further elaboration of these genera and the similar treatment of others will follow as rapidly as the results from field, garden, and herbarium can be obtained.

Taxonomy of Haplopappus, by H. M. Hall.

As a result of intensive herbarium studies, following several years' work in the field and garden, it is developing that practically all of the numerous genera proposed as taxonomic segregates from *Haplopappus* are based upon insufficient evidence. Many of these segregates seem generically distinct when considered locally, but their maintenance becomes impossible when all of the connecting species are assembled from the entire range of the genus. The most logical and useful treatment, therefore, is to accept *Haplopappus* in approximately the sense of Bentham and Hooker and of Gray, but with certain readjustments between it and related genera, especially *Bigelovia* and *Chrysothamnus*, these changes being necessary in order to establish the groups upon a phylogenetic basis. The natural subgenera, all of which have been given generic rank at one time or another, are: *Hazardia*, *Isocoma*, *Ericameria*, *Pyrrocoma*, *Isopappus*, *Stenotus*, *Macronema*, *Tonestus*, *Prionopsis*, *Oreochrysum*, and *Oonopsis*. A phylogenetic arrangement of these has been prepared, and their relation to other subgenera of South America has been indicated. A full taxonomic account of the species, subspecies, and minor variations, based upon field, experimental, and statistical studies, is now in progress.

Taxonomy of the Madieæ, by H. M. Hall.

This subtribe of the Compositæ is restricted almost entirely to the Pacific Coast of North America. It is, therefore, especially suitable for garden experiments carried on within this area and, since the species are accessible for field and statistical studies, the group is an ideal one for intensive phylogenetic investigation. Garden cultures started some 10 years ago are now undergoing considerable extension. During the autumn of the present year seeds of about 50 forms were collected in various parts of California. These will be used in greenhouse and garden experiments designed to test the nature of characters employed in the classification of the genera, species, and smaller taxonomic units.

Dr. M. C. Mann, of the Division of Genetics, University of California, has studied the chromosomes of 6 forms grown in the botanical garden and reports 12 pairs each for *Hemizonia congesta*, *H. rudis*, *H. lutescens*, *H. citrina*, and *H. grandi-flora*, but 10 pairs for *H. corymbosa*. This tends to support the taxonomic view, arrived at through field and cultural studies, that all five species first named are very closely related and perhaps to be treated as subspecies and minor variations of *H. congesta*, the earliest name for the group, while *H. corymbosa* belongs to a different subgenus.

Rubber Plants, by H. M. Hall and Frances Long.

A revived national interest in the rubber situation has led to cooperative arrangements with the United States Department of Agriculture for the study of native rubber plants. Special attention is being given to species of *Chrysothamnus* and *Asclepias* recently discovered to contain rubber, as reported in earlier editions of the Year Book. Plans for experiments have been formulated and these are now being carried out by the Department's representatives at Fallon, Nevada, for *Chrysothamnus*, and at Bard, California, for *Asclepias subulata*. The numerous subspecies and minor variations of *C. nauseosus* are being rapidly assembled at the former station with a view to utilization in breeding and selection and for the study of their behavior, especially as regards rubber-content under different ecological conditions. Wherever possible, the forms are introduced both by means of seeds and through the transplanting of individuals. In the latter case, detailed records are preserved for each individual, so that any change in its characters may be fully studied. Since reciprocal transplants are made between related forms, the results will also be directly applicable in fundamental studies on the taxonomy of this genus of shrubs. Similar work is under way with *Asclepias* and it is intended that the results from both series of investigations shall supplement those of other studies in experimental taxonomy, as described above. Further work has been done on the ecology, distribution, and growth of *Asclepias subulata*, and the results of pruning experiments are now becoming available. The cortex of the stems and especially that of the younger portions has been found to contain the best rubber, as well as much the largest amount. A number of other species have been analyzed for rubber during the year, especially the spurges, but none have shown a sufficient quantity to warrant further consideration.

Latex and Laticiferous Tissue, by Frances Long.

The histological study of laticiferous tissue in a wide range of genera has been continued, and seedlings have been grown to permit a study of the origin of the three types of latex vessels. In this connection, particular attention is being given to the storage of starch and resins in latex-bearing plants and its relation to the milk tubes. An endeavor is also being made to determine the fate of the latex in the various organs at the close of the season. Several species of *Asclepias*, *Euphorbia*, *Campanula*, and *Cichorieæ* are being grown under different conditions of water and light in the hope of disclosing factors that produce variation in the amount of latex and its rubber-content, both under control and in nature.

Experimental Vegetation, by F. E. Clements and J. E. Weaver.

Studies in experimental vegetation begun in 1919 were continued during 1923 with the primary purpose of obtaining another season's results to compare with those of previous years and also to measure by phytometers the differences indicated by instruments and the behavior of native plants (cf. next two sections). As heretofore, the stations maintained extended from the subclimax prairie at Nebraska City to true prairie at Lincoln, Nebraska, mixed prairie at Phillipsburg, Kansas, and short-grass plains at Burlington, Colorado. At Lincoln the local stations ranged from xerophytic gravel-knoll, through high prairie, low prairie, and salt-flat, to swamp. During 1922 the average germinations under all methods of planting, viz, surface sowing, trench, and denuded quadrat, were 75, 74, 67, 63, and 44 per cent at Lincoln (low and high prairie), Nebraska City, Phillipsburg, and Burlington, respectively. Establishment in the same sequence of stations was 50, 62, 46, 39, and 26 per cent. The average losses of all plantings for the past 3 years during the fall and dry winter (1922-23) were 16 per cent at Lincoln (high prairie), 29 per cent at Phillipsburg, and 46 per cent at Burlington. In concluding the work, tables are being compiled showing for the several stations the average percentage of germination for the three or four years and the average percentage of establishment, as well as the percentage of survival at the end of each year for the several methods of planting and transplanting. For example, in denuded quadrats at Nebraska City, planted in 1920, there was 100 per cent survival at the end of the first season, 90 per cent at the end of the second, but only 80 per cent by the end of the third year. Average germination for 3 years gave 81, 70, and 42 per cent, respectively, at the true and mixed prairie and short-grass plains stations.

Growth-rate and transpiration-losses were obtained at the three last-named stations by the use of batteries of 6 to 12 plants of each of the following species in sealed and aerated containers of appropriate size to permit fairly normal root development. *Helianthus annuus*, *Acer negundo*, *Avena sativa*, and *Elymus canadensis* were grown, when two or more weeks old, for periods of 14 days at each of the stations. The results are not only in fair agreement with factors as measured by instruments, but also correlate well with the behavior of the seeded and transplanted vegetation. The results of the experiments over a period of 5 years are now being assembled for publication.

Water-Loss from Vegetation in its Normal Soil Relation, by J. E. Weaver and John W. Crist.

The following method has been devised to overcome the objection of measuring transpiration from plants grown in soil of disturbed structure and to make it possible to measure the water-loss from areas of undisturbed stabilized vegetation. A heavy galvanized iron cylinder with cross-sectional area of 1 square foot was started into the soil in the opening left by a heavy steel cutter of similar diameter which had been driven to a depth of 4 inches and then withdrawn. A trench 2 feet wide, dug around a row of these cylinders, permitted columns of soil, over which the cylinders fit tightly when forced downward, to be cut to a depth of 3 feet. Loose-fitting bottoms with upturned edges were then placed over the lower ends of the cylinders after the soil columns had been cut away. Containers and soil were then weighed, placed in an appropriate trench in undisturbed grass-land, the bottoms made water-tight by the addition of a wax seal, and the narrow trench refilled. After a 15-day interval, during which the containers were covered in case of rain but watered as necessary, they were reweighed and the water-losses determined. Thus, it was found that *Bulbilis dactyloides* sod in the short-grass plains (Burlington, Colorado) lost nearly a pound of water per day, *Agropyrum glaucum* lost more than a pound, and an equal area covered with a similar carpet of dead grasses lost only one-third of a pound, which was less than that from bare soil. In mixed-prairie (Phillipsburg, Kansas), *Bouteloua gracilis* lost 15 pounds in a 15-day period and *Andropogon furcatus* lost 28 pounds. Losses from similar vegetational areas in the true-prairie (Lincoln, Nebraska) were less. Crops of oats, millet, and alfalfa gave equal or greater losses than the native vegetation at the several stations.

Plant Production as a Measure of Environment, by J. E. Weaver.

In connection with the studies in experimental vegetation (p. 311), an attempt has been made to determine the precise relation between habitat factors as measured by instruments and plant response as determined by growth. At each of the stations in the three grassland associations, all of the important aerial and edaphic ecological factors, such as rainfall, holard and nutrient content of soil, humidity, evaporating power of air, soil and air temperature, and wind movement, were measured and compared during three growing seasons. The production of native grasses and the smaller cereal crops was determined by means of a large number of cut quadrats. The relative production of certain legumes and maize was also ascertained. The yield of pure or mixed stands of grasses increased progressively as the water-content of soil and inversely as the evaporating power of the air, i.e., proceeding from the western stations eastward.

Average yield of cut quadrats in grams, 1920, 1921, and 1922.

Dominant vegetation.	Burlington.	Phillipsburg.	Lincoln.	Burlington.	Phillipsburg.	Lincoln.	Burlington.	Phillipsburg.	Lincoln.
Buffalo grass	98	290	......	207	266	235	179	260	......
Wheat grass	500	541	......	400	457	606	......	334	541
Mixed short and tall grasses	197	313	......	......	......	......	263	365	......
Mixed tall-grasses	......	410	458	......	477	755	......	287	413
Average (based on number of quadrats)	183	378	458	353	402	603	224	311	447

The same relation was determined not only for oats, wheat, and barley, but also for alfalfa and sweet clover as well as for maize. For example, the dry weight of stalk of maize was, in the above sequence of stations, 64, 83, and 100 per cent and the dry weight of ear was 45, 59, and 100 per cent. Thus, native and crop plants are shown to integrate environmental conditions and to express them quantitatively in yield.

Relation of Holard to Root Development and Yield, by F. C. Jean and J. E. Weaver.

Crops of Marquis spring wheat, corn, alfalfa, sugar-beets, and potatoes have again been grown in plats of one-thirtieth of an acre each at Greeley, Colorado, on dry land and under semi-irrigated and fully irrigated conditions. The main objective was to determine the effect of different quantities of water on root development and yield. The root development of each of the crops was studied in several stages of growth under each environment. The rainfall during the past summer has been abnormally high, and the factors of temperature, humidity, and evaporation, (continuous records having been kept during two seasons) as well as the holard, are very different from 1922. However, none of the aerial factors at the several stations were very different for either season, so that after allowing for physical and chemical differences of the soil direct correlations with variation in root habit and holard were determined. Root development in the dry land was limited by the depth of moist soil, the roots of all crops being largely confined to the surface 3 feet. Major branches were most abundant in the surface 18 inches and showed a more marked tendency to penetrate downward than those in the fully irrigated plats, which also often originated at greater depths and spread widely in the moist mellow soil. Depths of 5 to 8 feet were commonly reached by the root systems under the latter conditions. Smaller branches were greater in number, longer, and more abundantly rebranched in the dry land. In semi-irrigated soil, conditions were intermediate, deep penetration being accompanied with profuse branching. For example, fully mature corn reached working depths of 32, 40, and 58 inches in the dry-land, fully irrigated, and semi-irrigated plats, respectively, the stalks in the dry land being 3 feet and in the irrigated fields 7 feet tall. Maximum depths in the same sequence were 44, 70, and 80 inches. The rate of branching ranged from 20 to 25 per inch in dry land (average length 4 inches) to 12 to 20 (average length 2 inches) in fully irrigated soil. The moister soil of 1923 gave an excellent opportunity of studying root behavior in the same soil under different degrees of water-content.

Destruction of the Range by Prairie-dogs, by W. P. Taylor and J. V. G. Loftfield.

Quantitative determinations of the damage done to the range at two of the stations in northern Arizona gave the following results:

Wheatgrass forage type (4 years' determinations, Coconino, Arizona).	
Proportion of western wheatgrass destroyed by prairie-dogs	69 per cent.
Proportion of western dropseed destroyed	99 per cent.
Proportion of total forage (combining the two grasses) destroyed	80 per cent.
Total forage produced per acre per year	1862 pounds.
Forage destroyed by prairie-dogs per acre per year	1495 pounds.
Blue grama forage type (1 year's determination, Williams, Arizona).	
Proportion of blue grama destroyed by prairie-dogs	83 per cent.
Total forage produced per acre per year	390 pounds.
Forage destroyed by prairie-dogs per acre per year	324 pounds.

The Zuni prairie-dog seems to prefer the western dropseed (*Sporobolus cryptandrus*) to the western wheatgrass (*Agropyron smithi*). The latter apparently endures grazing by both prairie-dogs and stock better than the former. Where all three are present, blue grama (*Bouteloua gracilis*) appears to be third in order of preference. Prairie-dogs and cattle feed on the same grasses and prefer them in the same order. Prairie-dogs do not, from all the evidence obtained from 4 years' observation, eat anything that cattle do not; thus they are thrown into direct and often (in times of drought) deadly competition. So far as these experiments go, the prairie-dog can not be said to have a single beneficial food habit. In some overgrazed areas, the total eradication of prairie-dogs as well as reduction in the number of cattle per unit area will be necessary if the forage is to continue to exist.

Soil Fauna, by G. W. Goldsmith.

The Berlese extraction apparatus has been improved by the addition of a thermo-regulator, so that extraction can be carried out under approximately constant temperature. By employing soil which has been thoroughly heated and adding a known number of organisms, the efficiency of the apparatus in removing the soil fauna can be determined. Preliminary results indicate that the efficiency is not the same for the different groups of organisms in the gravel soil used, but is highest for the *Acarina*. The average efficiency under conditions as usually employed is not far from 50 per cent, but this may be considerably improved by careful temperature-control and by the limitation of depth of soil placed on the screens. As a consequence it has proved possible to refine the results of other observers and to check and extend the observations already made on the soil fauna of the Pike's Peak region.

Principles and Methods of Bio-ecology, by F. E. Clements and W. P. Taylor.

The field investigation of the biome, embracing the rôle of the animals in it, their relation to succession, and the interrelations with plants, has been continued throughout the year, while those aspects of it that are concerned with pollination and migration, soil fauna, and grazing research have received especial attention during the growing season. The quantitative methods applied to the plant community have been found increasingly applicable to the biome, with such modifications in certain instances as are demanded by the habits of motile organisms. It has become obvious that the developmental system alone gives an accurate and adequate view of the biome with its complex of action and reaction between plants and animals and between these and the habitat. Attention has been focused chiefly on the basic problems of the biome in the grassland formation, not merely because this is the most extensive and diverse, but also because it is most subject to modification by animals, the latter are most abundant and most readily visible in it, and the correlations and reactions between the plants and animals are most evident. The desert also offers some of the same advantages, though the number of animals is much smaller. This was strikingly exemplified in Death Valley, where few were to be found in the climax areas, while the hydrosere in the several ponds at Saratoga Springs yielded more than 20 species of birds and a corresponding number of other animals. For somewhat similar reasons the insects, birds, and rodents are the animal groups that have received first consideration. At the same time an endeavor has been made to project into the past the results and principles wrought out in the biome of to-day, in the hope of refining the methods and conclusions of paleo-ecology. A comprehensive survey of the literature on the animal side has been initiated with the object of bringing together all the results of definite ecological nature which bear on the problems of the biome.

Climax Formations, by F. E. Clements and E. S. Clements.

Practically all the associations of the 9 climax formations which occupy the West have been traversed in the course of the 12,000 miles traveled by motor during the year, the majority of them receiving both intensive and extensive study for periods of several weeks to a month or more. This has permitted a closer and more direct comparison of the associations of each formation and a more detailed scrutiny of the ecotones between the various climaxes than has been possible heretofore. One result of fundamental importance has been to broaden the relationship between the associations and to enhance the unity of the climax. This has been most striking in the case of the grassland formation, because of its greater extent and diversity, but it applies with almost equal force to the scrub and forest climaxes.

The grassland associations have been studied almost through their entire extent. The bunch-grass association was examined from the Mexican border through California and Oregon to northern Washington and thence eastward to Utah. This revealed greater unity than was known to exist between the southern and northern portions and made it possible to trace the contact between the bunch-grasses and the tall-grasses which formerly dominated the northeastern portion of the Great Basin. While previous observations indicated that the bunch-grass prairie once extended to western Wyoming, it was found that this was true only of the foothills, and that the plain proper was covered with such tall-grasses as *Stipa comata*, *Agropyrum glaucum*, and *Sporobolus cryptandrus*. The behavior of the short-grasses and sedges was studied along their western frontier and a mass of additional evidence was obtained as to the universal conversion of the mixed-prairie climax into the short-grass subclimax in response to overgrazing. The mixed, true, and subclimax prairies and the intervening ecotones were examined from Colorado through central Nebraska to Kansas and Missouri, and the subclimax prairie was then traced to southeastern Texas to its contact with the coastal prairie on the south and the southern mixed prairie on the west. In western Texas the latter passes rather abruptly into the desert plains, which extend well beyond central Arizona, finally yielding to the true climax of desert scrub.

The desert-scrub formation was again examined through the Colorado and Mohave Deserts and in addition its structure and development were studied throughout Death Valley and the adjacent valleys to the east. This corroborated the recent conclusion that in the United States at least this climax is confined to the desert regions along or near the lower course of the Colorado River and that the extensive areas of *Larrea* and *Prosopis* that reach from Texas to Arizona are actually savannah. The coastal forest and its outposts were followed from central California to northern Washington and the transition association of the same climax through eastern Washington and Oregon, while the structure and zonal relations of the montane and subalpine forests were seen in the Sierra Nevada, on Mount Rainier, and in the Cascade and Blue Mountains of Oregon and Washington.

Changes in Grassland, by F. E. Clements and E. S. Clements.

While further evidence of the widespread changes in grassland in consequence of climatic cycles, grazing, and fire has been obtained from all of the associations, perhaps the most striking of this has to do with the differentiation of the bunch-grass prairie, the tall-grass savannah of the northern portion of the Great Basin, and the original grassland of Death Valley. An unusual opportunity has also been afforded for the study of natural parks and savannah in widely separated regions. The major dominants of the bunch-grass climax differ so completely in southern and central California from those of northeastern Oregon and adjacent Washington as to raise a serious question of their former continuity and actual relationship. In the southern portion of the climax, *Stipa setigera* and *eminens* are overwhelmingly predominant, while in the north these do not occur, and *Agropyrum spicatum, Festuca ovina,* and *Poa sandbergi* outrank all their associates. While an undoubted differentiation has occurred, due in part to climate and in part to mountain barriers, a careful scrutiny of hundreds of relict areas, especially in the intermediate region, indicates that originally these were essentially a unit. Although *Agropyrum spicatum* and the two *Stipas* have nowhere been found in contact to-day, they existed as co-dominants in the intermediate region within the historical period and many of their associates range throughout. Thus, *Koeleria, Poa, Sitanion, Elymus,* and *Stipa comata* occur through practically the entire association and *Danthonia* and *Melica* through most of it. The divergence of the two portions doubtless owes much also to the fact that fire and overgrazing have opened the way to the annual grasses to become dominant in California and the sagebrush in Oregon and Washington.

It has been assumed until the present season that the sagebrush savannah that covers the northern and eastern part of the Great Basin had developed from the bunch-grass association. The investigations of the summer, however, make it clear that this is true chiefly for the portion found in eastern Oregon and Washington. The grasses of the major part of this community are the tall-grasses of the mixed prairie, *Stipa comata, Agropyrum glaucum, Sporobolus cryptandrus,* and *Kœleria cristata.* The short-grasses, *Bouteloua gracilis, Carex filifolia, Bulbilis dactyloides,* and *Hilaria jamesi,* have not been seen west of the Teton and northern Wasatch ranges, though the first two have been recorded for Washington. Thus, it appears probable that both the elements of the mixed prairie were once in contact with the bunch-grass climax in the north as well as in the south, though the short-grasses were clearly fewer and much less abundant.

The contact between grassland and forest has been traced along a greater front than in any previous year. This has permitted an exceptional opportunity for studying the relation of natural parks and savannah to each.

Park and savannah are evidently different expressions of the same climatic tendency as wrought out in the ecotone between grassland and forest at the foot of mountain ranges generally or all over their slopes when they are low, as is often true in the Coast Ranges. Savannah is practically confined to such, with occasionally a slight development at the alpine timber-line, but natural parks are regular successional features of the valleys in the montane and subalpine forests of the Sierra Nevada, Cascade, and Rocky Mountains. Perhaps the most striking examples of the latter are found on Mount Rainier, where the deep snows are a contributing factor. The Coast Ranges of California furnish what is at first glance a puzzling arrangement of grassland, savannah, natural parks, and climax forest relicts on northerly slopes, but repeated study supports the conclusion that these are primarily a response to climatic cycles as expressed locally in slope-exposure and regionally in proximity to the ocean and hence in precipitation.

The Original Vegetation of Death Valley, by F. E. Clements.

The reconstruction of the original grassland vegetation of the Colorado and Mohave Deserts (Year Book 21, p. 350) rendered it probable that relicts of a similar grassland would be found in Death Valley, and an expedition with this as one of the chief objects was made into the latter in early spring. The floor of the valley proper, consisting of the periodically dry plain of the Amargosa River, is so intensely saline that the only grasses found were *Sporobolus wrighti* and *Distichlis spicata.* About Bennett's Well these were sufficiently abundant to maintain a small herd of cattle. It is probable that annual grasses develop in the less salty areas during a normal season, but none were seen in this year of exceptional drought. Over the extensive plain above Furnace Creek Wash, *Stipa speciosa* and *Eriocoma cuspidata* were very frequent, the individuals often being so abundant as to give the appearance of savannah to the *Larrea* climax. On lava ridges with their greater water-supply owing to the reduced competition of the shrubs, *Aristida purpurea* was the chief grass, with more or less *Stipa*, *Trisetum pulchellum*, and several annual grasses, such as *Festuca tenella* and *Bromus rubens.* The best relict areas were naturally found at the higher levels, the north slope of the Avawatz Mountains at about 4,000 feet yielding the best picture of original conditions. Here *Stipa speciosa* was dominant on south subslopes in an open savannah of low shrubs, frequent mats of *Hilaria jamesi* and *rigida* with subcopious *Aristida* and *Stipa* on the east, and *Poa fendleriana*, *Stipa*, and *Hilaria* on the north subslopes. With the exception of *Hilaria jamesi* and *Poa*, which occur in the general region, all of these are likewise found in protected areas in the Mohave Desert, especially in sand with its more constant water-supply, and it seems certain that the same grassland climax occupied both regions before the last dry phase, which permitted the entrance of the *Larrea-Franseria* climax.

Application of the Relict Method, by F. E. Clements.

The basic importance of relict species and communities for tracing the major changes in vegetation has been further exemplified in the study of the various climaxes. Such changes are usually the result of the shift of the climatic cycle, or of grazing, cultivation, or fire. Each of these processes is in general typical of a certain region or climax, and its effects, though not confined to it, can best be investigated there. Thus, while climatic changes have clearly left their mark on each of the great formations, this is most pronounced in the Southwest, where under a minimum rainfall a small decrease produces a large effect. Likewise, all communities have been modified to some extent by grazing, but grassland and especially those associations in an arid climate have been changed the most, while the reverse is true of cultivation in the West. This is universal only in humid or subhumid regions, and its maximum effect is consequently to be found in the subclimax and true prairies. Fire, on the contrary, has but relatively little effect on grassland, while it modifies forest profoundly and often scrub also. In the communities changed by each of these processes the relicts have their own peculiar significance, though all are in harmony with the general principle. This is to the effect that the relict plant or community is one that has enjoyed a certain degree of protection against the destruction due to changes of climate, to grazing, cultivation or fire, and naturally also to other minor destructive processes. The persistence of such relicts is due to the fact that plants once thoroughly established have a much better chance of adjusting themselves to changing conditions than seedlings do, the hazards for practically all species being far the greatest during the first year. Hence the study of the changes in vegetation that are occurring or have occurred in the last few thousand years is first of all a search for protected places or regions in which former dominants or subdominants have been able to persist. In the case of climatic changes these are valleys, sandhills, and higher altitudes during the dry phase and exposed slopes and ridges during the wet. They are primarily areas fenced against cattle in the case of grazing, and those untouched by plowing, pasturing, or building in the case of cultivated regions. Fire relicts regularly result from changes of wind or weather, differences of density, slope, land-form, barriers, nature of the fire, etc. These afford explicit evidence upon which the reconstruction of past vegetation can be based, current changes followed, and future ones depicted.

Rainfall and Climatic Cycles, by F. E. Clements.

The investigation of the rainfall of the western United States and Canada in relation to the sunspot cycle has been continued during the year. The tables for more than 1,000 stations are being checked against the new edition of the section summaries of the Weather Bureau, and it is hoped to publish the results of the study soon after all these have become available. In order to afford a larger number of records extending back beyond 1860, some of the longer records of the East are also being taken into account. Rainfall records from widely separate countries in the other five continents are likewise being assembled in order to ascertain whether they exhibit cycles and whether these bear any relation to the sunspot cycle.

In the endeavor to evaluate some of the factors in rainfall and to discover a possible connection with rainfall cycles, a preliminary series of measurements has been made of the water-loss from natural vegetation and cultivated crops in midsummer. These have been carried out at Lincoln, Nebraska, in the true prairie with a rainfall of 29 inches; at Phillipsburg, Kansas, in the mixed prairie with a rainfall of 23 inches; and at Burlington, Colorado, in the shortgrass plains with a rainfall of 17 inches. While climatologists have more than once shown that the planting of crops in the prairie States has not resulted in an increased rainfall (cf. Loveland and Swezey, The rainfall of Nebraska, Bull. 45, Nebr. Agr. Exp. Sta., 1896), the opinion still prevails that rainfall has increased with cultivation and is continuing to do so. The results show that one native species, *Andropogon furcatus*, transpired 27.6 pounds per square foot of sod during a 15-day period, while a similar area of oats lost but 15.55 pounds. Wheat-grass, *Agropyrum glaucum*, transpired 90 per cent as much as millet, and lowland prairie sod at Lincoln 80 per cent as much as alfalfa. When the much longer period of growth is taken into account, it is evident that the native grasses lose as much water in the growing season as the ordinary crops, with the possible exception of corn. More significant, however, is the fact that even the short-grasses transpire more water in a season than the annual rainfall at Phillipsburg or Burlington, while the loss from bluestem is approximately twice the annual rainfall.

Methods and Principles in Palæo-ecology, by F. E. Clements and R. W. Chaney.

The preliminary organization of the new field of palæo-ecology, outlined in *Plant Succession* (1916) and *Scope and Significance of Paleo-ecology* (1918), has been tested and expanded by the application of the methods and principles to the fossil flora of the John Day Basin. This has involved the trial of the basic methods of quantitative and developmental ecology as exemplified in association, succession, phylogeny, climatic cycles, migration, and adaptation especially, and this has progressed far enough to show that the fossil material in many formations is adequate for far-reaching reconstruction, when sufficiently refined and utilized in accordance with proper ecological principles. In this connection it has proved imperative to check all the evidence drawn from leaf-impressions, by means of wood sections and fruits so far as the latter are available, but especially to make use of the range of variation as shown by modern plants of the same or related genera and species. This has fully confirmed the original working hypothesis derived from the principles of climatic cycles and association (*Plant Succession*, p. 362), namely, that modern species appeared much earlier in the Tertiary than has been supposed and that tropical genera could not be expected to thrive in the same climaxes as temperate or boreal ones. It also lends further support to the view that climatic climaxes were differentiated on the North American continent during the early Mesozoic and that in the Tertiary they closely resembled those of to-day in character if not in extent. The hypothesis which links the origin of Angiosperms with Permian climatic cycles and regards the highest types, the grasses, oaks, etc., as evolved by similar changes during the Mesozoic, is placed on a correspondingly firmer basis. In conformity with rapidly accumulating evidence as to the present, migration in the past appears to have been primarily a response to the alternating phases of climatic cycles, the climaxes expanding or contracting with wet and dry phases but never disappearing. A progressive but slow differentiation of species went with this, nicely illustrated by the fact that Miocene and Oligocene forms of widespread boreal species usually resemble Eurasian subspecies more than American.

Biotic Succession in Bad Lands, by F. E. Clements.

The usual number of bad-land regions have been examined during the year, extending from Arizona to Oregon and from California to Texas, and ranging in time from the Permian to the Pleistocene. In California the chief formations were the Miocene of Death Valley, the Monterey, and Fernando; in Oregon and Idaho, the Payette; in Wyoming, the Laramie, Wasatch, Bridger, and Green River; in Colorado, the Pawnee Creek; in Nebraska, the Brule; in Texas, the Permian; and in Arizona, the Pliocene and Pleistocene. Attention was focused primarily on present-day succession in these areas and the relation of this and erosion to the existing climatic cycles. Along the northern flank of the Uinta Mountains the relation of the axis to the massive Eocene deposits, the significance of the very unequal slopes, and the nature and development of the sedimentation areas again received consideration. Because of the great amount of material accumulated during the past 10 years, as well as the diverse interests represented, it seems best to treat bad lands in three separate publications, one dealing with recent changes in climate and vegetation, the second with the present climaxes and seres, and the third with their paleo-ecology. The first of these is now in preparation.

Succession in Dunes and Sandhills, by F. E. Clements.

Several dune and sandhill areas have been revisited and a number of new ones examined during the field season. These may be conveniently grouped in four types, in accordance chiefly with the originating area. The coastal dunes were seen along the California littoral at La Jolla, Oceano, Montara, and Eureka, and the lacustrine ones in the Algodones of the Colorado Desert, those near Coachella on the Salton Sea, and probably also the larger dunes near Saratoga Springs in Death Valley. Fluvial dunes were examined along the Columbia River in Washington and Oregon and along several of the streams of Kansas, Oklahoma, and Texas. A considerable number of sandhill areas have been studied in eastern Colorado and western Nebraska, western Texas and southern New Mexico, all of which probably had their origin as fluvial dunes. In addition to tracing the course of succession in the various types and climaxes on a comparative basis, considerable attention has been devoted to the ecesis and life-history of the dominants. Furthermore, sandhills and old dune areas are often of great value as places of survival of relict communities, and thus furnish decisive evidence as to recent climate and vegetation. This is best illustrated, perhaps, by the great sandhill region of central Nebraska, which exhibits many dominants of the true and subclimax prairies, though it is chiefly in the climate of the mixed prairie.

Permanent Quadrats and Transects, by F. E. Clements and J. V. G. Loftfield.

The quadrat work has been expanded until 300 quadrats are being charted at the end of each growing season or oftener, and almost as many more are charted at longer intervals. Many of these have been charted for 6 years at regular intervals. They have been tabulated during the year and the data are at present being compiled. So much of interest has been found and so many new methods developed that it is felt advisable to arrange the material for publication at an early date.

The standard quadrat is 1 meter square and at present is charted on a scale of 1 to 5 or on a chart 2 dm. square; but since alpine vegetation consists of very numerous small plants, it has been found very difficult to use this unit. Accordingly a special quadrat 4 dm. square has been adopted for this and similar types of vegetation, and this is charted on a scale of 1 to 2 on the same form of sheet as used for the standard quadrat. Such alpine quadrats have been established in addition to the older ones on the top of Pike's Peak and charted once a month during the past season.

Transplant quadrats have been installed in three of the six formations in the Pike's Peak region for the purpose of studying the relation of grass stages in them to each other and measuring the effect of climate and competition upon the dominants. Each is 1 meter square, with an area 5 dm. square removed from the center and replaced by the sod from a corresponding quadrat in some other formation. Such quadrats have been established in the Garden of the Gods in the Petran chaparral, one containing sod from the upper edge of the montane forest, the other a sod from the alpine meadow. At the Alpine Laboratory are two corresponding quadrats with sods from the chaparral, the alpine meadow formation, and reciprocal ones are located in the alpine meadow.

A number of lichen and moss quadrats have been established for the purpose of measuring quantitatively the rate of change and the composition of the earlier stages of the xerosere. These are not charted in the ordinary manner but are photographed. Two sizes are used, one a decimeter square, which is photographed natural size, and more commonly one 2 dm. square, which is reduced to one-half in the photograph. The latter are mostly paired and one quadrat in each pair has a square 8 cm. in size chiseled out of the exact center. The rock in most cases has been bared to sufficient depth to expose a practically unweathered surface. In certain of them, lichens or mosses have been transplanted by attaching them to the rock in various ways.

Grazing Research, by F. E. Clements, J. V. G. Loftfield, and H. M. Hall.

The regular field work on the relation of varying rainfall to the composition and carrying capacity of the range, on the indicators of optimum grazing and overgrazing, and the effects of the latter has been carried on in the various climaxes throughout the year. Several new exclosures have been installed, and a large number of additional quadrats, transects, and tristats established, especially on the Santa Rita Range Reserve, in northern Arizona, and at the Sonora Substation in western Texas.

In the Sierra Nevada several small exclosures have been fenced on the westerly slope at 4,500-feet altitude, and two in the sagebrush association at a similar altitude on the east side of the range, while extensive protected areas at Tuolumne Meadows in the Yosemite National Park will serve a similar purpose for species adapted to high altitudes. These areas, all of which have been previously overgrazed, are intended to serve as stations for the study of succession and of ecology of forage plants of this particular region.

Research in Hay-Fever.

PACIFIC COAST AND GREAT BASIN, BY H. M. HALL.

Cooperative studies with clinicians and practicing specialists on the Pacific Coast have been intensified during the year. In addition to the more elementary work, such as the preparation of pollen surveys and the investigation of hay-fever pollens, a beginning has been made in the fundamental principles of group reactions. It now seems probable that a correct botanical classification, when once worked out, will indicate the limits to which the practitioner can go in assembling the species of pollen plants into groups, any member of which may be used interchangeably with any other of the same group. The principle underlying this method is that both the botanical and the clinical groupings are at base chemical in nature.

In order to test the parallelism between the botanical arrangement and the pollen reactions, there have been prepared lists and charts showing the different degrees of relationship between species of several of the more important genera and families. These are now used as a basis for experiments as suitable subjects become available in the clinics. Preliminary experiments seem to indicate that in certain plant families the proteids are closely similar even in different genera, whereas in other families there is a sharp distinction between the reactions obtained even from species of close relationship.

ROCKY MOUNTAIN AND MISSISSIPPI VALLEY REGIONS BY F. E. CLEMENTS, W. V. MULLIN, R. J. GILMORE, AND J. H. C. SMITH.

Excessive rainfall over much of the Middle West prolonged the flowering period for the most important hay-fever plants and correspondingly increased the growth and pollen production. Daily analyses of the pollen-content of the air were made at Colorado Springs, whenever the weather conditions permitted, by means of an anemometer which measured the air passing over pollen-plates as an automobile was driven through the district to be tested. This preliminary study warrants the following conclusions: (1) rain clears the atmosphere of pollen grains; (2) the amount of pollen in the air varies with the velocity of the wind; (3) the pollen in the air reaches a maximum within 1 to 3 hours after the anthers have shed. This maximum usually falls between 8 and 11 o'clock in the morning, but is affected to some extent by the air-currents.

In connection with the vegetation studies being made throughout the West, a survey has been begun of the detailed distribution of wind-pollinated species, especially along roadsides and in the vicinity of towns. While the most important species are more or less generally present in a particular state or region, they may range from dominant to absent in any particular locality, and a knowledge of their exact location and abundance is alone of practical value to the physician or hay-fever patient.

Among the clinical results of the year perhaps the most interesting dealt with sensitivity to different pollens in regard to the evolutionary relationship of the species concerned. While four species of sagewort, *Artemisia*, belonging to three different sections of the genus, are abundant in the vicinity of Colorado Springs, one of them, *A. campestris*, appears to suffice for the diagnosis and treatment of hay-fever due to any of the group. On the other hand, there is usually a difference in the intensity of reaction to the three species of *Ambrosia*, and a number of patients react to one but not to the other. Patients sensitive to *Ambrosia* regularly respond to the related genera, *Iva* and *Franseria*, though in varying degree. Among the goosefoots, the Russian thistle (*Salsola*) and lamb's-quarters (*Chenopodium*), although not closely related in the same family, possess pollen grains all but identical in appearance and are equally effective, though about one-fifth of those treated react to one and not to the other. The related summer cypress (*Kochia*) is less than half as effective, probably because of its less abundance. Three-fourths of those tested during the season reacted to the pollen of four or more species, while one-fourth responded to but three pollens or less, five alone being sensitive to a single one. The advantages of pre-seasonal treatment are brought out clearly by the fact that this yielded an average relief of 90 per cent, in contrast with 50 per cent for seasonal treatment, though this also gave complete relief in some cases. The necessity for the use of local survey and pollen-plates in complete diagnosis is well illustrated in the case of a patient who had always resided in Colorado Springs but failed to react to the pollen extracts of 29 species occurring there.

On the chemical side a considerable number of pollens have been analyzed with respect to their composition, especially as to albumins and globulins, and preliminary attempts have been made to determine the precipitation effects of these and of the various pollens.

GEOLOGY.

Antevs, Ernst, University of Stockholm, Sweden. *On the Pleistocene history of the Great Basin.*

In July and August 1922 the writer studied the deposits in the ancient lakes Lahontan, Bonneville, and Mono, in the Great Basin, in order to get a better knowledge of their Pleistocene history and to be able more accurately to connect this with the history of the northern part of the continent. It was hoped that the clays deposited in the lakes would show annual lamination, eventually enabling direct correlation between the high-water stages in the Great Basin and the disappearances of the ice sheets in the North, but the sediments were found on the whole to lack seasonal banding. In the memoir submitted to the Carnegie Institution of Washington the times of the lakes, therefore, have been discussed from a broad climatological basis. An analysis and review of the climatic conditions during glaciations and during the postglacial epoch have been given. The chief events in the Great Basin have been found to have run parallel with the large events in the North. In the North four or possibly five glacial epochs, separated by warm interglacial periods, have followed each other. In the Great Basin, glaciations combined with expansions of the waters have alternated with arid periods. The high-water stages were due to heavier precipitation than at present and to little evaporation because of low summer temperature. The relatively heavy rainfall was connected with the changes of climate that checked the expansion of the ice sheets and caused their shrinking. It was a consequence of decrease of precipitation over the land ices, possibly caused by rise of temperature. The mountain glaciations and the slightly lagging high stands of the lakes in the Southwest were contemporaneous with the climaxes of the great glaciations and the first time of ice retreat. The arid periods, some of which may have been more pronounced than at present, corresponded to the interglacial epochs.

In the mountains in the Southwest records of three glacial epochs have been recognized, and in the Lahontan Basin sedimentary records of three or perhaps four, in the Bonneville Basin of two, and in the Mono Basin of two or perhaps several high-water stages are known at present. Doubtless there were in the Southwest as many glaciations and lake stages as there were glacial epochs in the North, and the last ones corresponded to the last glacial epoch—that is, they date some 30,000 years back.

As the ice sheets disappeared an adjustment of climatic conditions took place through which the belt of heavier rainfall again shifted northward. Shore lines below the highest stand of the Pleistocene lakes and alternations of beds of different coarseness indicate stationary lake-levels and small fluctuations during the general fall of the waters. While the post-Lahontan freshening of Pyramid and Winnemucca Lakes, Nevada, may have occurred by overflow through the Emerson Pass, 70 feet above Pyramid Lake, into the Smoke Creek Desert, Walker Lake, as lacking an adjacent evaporation pan, may have been dry at a later date, or some thousand years ago. Correlation between these fluctuations and the variations in width of the growth rings of the big tree had better be postponed till the factors of the radial growth become more satisfactorily known.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. *Study of fundamental problems of geology.* (For previous reports see Year Books Nos. 2–21.)

The usual investigations have been continued, but report on these is deferred to give place to the results of some inquiries in geo-climatic lines, to which considerable time has been devoted during the past year. An inquiry has been made into the ability of the several constituents of the atmosphere to serve as agencies of thermal storage, or, more specifically, an analysis has been made of the processes of heating and cooling the atmosphere with special reference to the time during which the various units of energy prolong their thermal action before escape from the atmosphere, together with the relationship of this to the time-factor of geologic climates. It may seem unnecessary to urge that the time of continuance of a given unit of energy in thermal action in the atmosphere is as essential to a true measure of its value as the number of such units in action. And yet, while this is not questioned, the time-factor has failed to receive the attention that has been given to the quantity-factor; indeed, certain phases of the time-factor have been almost ignored. Nearly all the heat received by the atmosphere enters it in the form of continuous chains of vibration, and the value of these *as chains* has naturally received first attention. These chains, however, are being continually broken into constituent units, and these units enter at once on their own courses of action, which run parallel in time with the original chains and enhance the total effect. The nature of these enhancing effects is the leading feature of this report.

The range of the report is limited to prolongation of thermal action in the lower atmosphere and the outer film of the earth, since these constitute the essential parts of the climatic zone as commonly understood and as geologically important. The geo-climatic field centers, broadly considered, on the contact zone between the troposphere, the hydrosphere, and the lithosphere. The more remote influences of the stratosphere and the still higher atmospheric zone revealed by meteor trains on the outer side and of the interior of the earth on the inner side are relatively negligible in a brief survey of essentials.

At the outset it is to be noted that the amount of heat which enters the climatic zone and the amount which escapes from it—which are approximately equal—do not alone determine the temperature within it, any more than the heat entering a room and the heat escaping from it alone determine its temperature. The detention and repetitive action of the heat are equally important. For example, W. H. Dines has estimated the mean atmospheric intake of solar energy at 360 calories per cm^2 per day and the escape as the same;[1] but he places the radiation from the earth's surface at 500 calories, while 200 calories are conveyed to the atmosphere by contact and otherwise; that is, 700 calories per cm^2 per day are in action near the contact zone between the earth and the atmosphere. This implies 90-odd per cent of repetitive overlapping or duplicate action. And yet doubling of the intake value is a small enhancement compared with what is very commonly attained in domestic and industrial practice, notably in the thermos bottle. Theoretically, the secondary or repetitive class of thermal actions may be high multiples of the incoming and outgoing values.

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[1] Quart. Jour. Roy. Meteorological Soc., vol. 43, pp. 151–158 (1917).

According to Dines, about one-half the energy of the solar rays outside the atmosphere is reflected to open space and has no heating value. In this the detention is nil. Thermally speaking, the time-factor is zero, and reflection thus serves as the bottom of the time-factor scale.

LEADING POINTS CONSIDERED.

A preliminary list of the main points considered may prove convenient:

1. Since a fraction of the solar energy is absorbed in penetrating the atmosphere (60 calories per cm^2 per day, according to Dines[1]), the question is considered whether absorption in the upper levels of the atmosphere gives larger or smaller total heating value before escape than would penetration to the earth's surface and radiation from the bottom of the atmosphere. The principles involved have several applications.

2. Since a larger percentage of solar radiation reaches the earth's surface (300 calories per cm^2 per day, Dines), questions have been considered relating to (1) the part that is reflected without delay and has no heating value, and (2) the part that is absorbed by soil, rock, and vegetation, which is soon given to the air (*a*) by contact, or (*b*) rendered latent by evaporation, or (*c*) absorbed and re-radiated as dark heat, or (*d*) retained by the ocean for long periods and carried far by its circulation.

3. Since the dark long-wave terrestrial radiation plays a large part in the climatic problem, questions have been considered relative to (*a*) the portion that escapes into space without absorption, (*b*) the portions that are absorbed by the several atmospheric constituents, and (*c*) the secondary courses these portions take, including the time-factors involved.

The consideration of the parts played by the several atmospheric constituents has been treated by grouping them into three classes, as follows:

(*a*) Constituents that have little or no power of absorbing (at ordinary atmospheric temperatures) terrestrial radiation and equally little or no power of radiating their own heat, however acquired. Nitrogen is the type of this group, but oxygen, argon, and the rare atmospheric elements are grouped with it for present convenience, with some reservations.

(*b*) Such permanent constituents as have little power of absorbing incoming solar radiation but readily absorb certain wave-lengths of the terrestrial radiation, and radiate this, as well as heat received from other sources. Carbon dioxide is the type and chief member of this group.

(*c*) Such temporary constituents of the atmosphere as (1) consume heat in their production by evaporation, (2) absorb readily terrestrial radiation and less readily solar rays, (3) readily radiate heat, however received, so long as they remain in the state of vapor, (4) give forth latent heat in passing back to the liquid or solid state, and (5) become efficient reflectors in this liquid or solid state.

RELATION OF INEFFECTIVE RADIATION TO THERMAL STORAGE.

By far the greater mass of the "permanent" constituents of the atmosphere are poor absorbers of solar rays (at least such as penetrate the lower atmosphere) and poor radiators of their own heat at ordinary atmospheric temperatures. The spectrum of nitrogen shows no lines of selective absorption or emission within the range of temperature of the lower atmosphere. Any ability that nitrogen may have to absorb such short vibrations as penetrate the uppermost atmosphere only is not here considered. Oxygen and argon are here classed in the same group but only with some reservations, for oxygen and argon have slight powers of absorption and radiation under ordinary atmospheric conditions. The oxygen derivative, ozone, is more notably absorbent of solar radiation, but it is essentially confined to the little-known tracts of the higher atmosphere, which are outside the scope of this report. It is not important to the merely general analysis here attempted that the nitrogen group shall be regarded as rigorously non-absorbing and non-radiating, but simply that they are so to an extent that differentiates them strongly from such absorbers and radiators as carbon dioxide and water-vapor.

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[1] Quart. Jour. Roy. Meteorological Soc., vol. 43, p. 151 (1917).

The climatic functions of this group may be suggestively pictured by imagining an atmosphere wholly made up of elements that neither absorb solar rays nor radiate their own heat, however received. The entrance and exit of heat, in this case, would be confined substantially to contact with the heated or cooled surface of the earth (neglecting, of course, such internal sources as expansion and contraction, friction, etc.). In considering such obstinate retentiveness, it becomes obvious that heat, once it has been incorporated in constituents of this class, would remain embodied in them for relatively long periods under average conditions because of lack of means of escape. This holds equally of their assembled state as a gas, for assembled states do not radiate as such. The time-factor would thus usually be distinctly large. This extreme theoretical picture is not fully realized in the atmosphere, but there is a sufficient approach to it to justify classing the main mass of the atmosphere as an effective source of detention or short storage of heat.[1] This is a property of the first order of importance in the maintenance of the thermal state of the earth's atmosphere. This property takes on considerable importance also in its working relations with the absorbing and radiating constituents, carbon dioxide and water-vapor.

PROLONGATION OF THERMAL ACTION BY CARBON DIOXIDE.

Since the main mass of the atmosphere is thus thermally conservative, the simplest step toward a concrete view of the working relations of its prolonging property is found in the study of a constituent of its own "permanent" type, but which readily absorbs terrestrial radiation and emits wave-lengths of its own type, carbon dioxide (CO_2).

While atmospheric CO_2 probably varies widely in amount from one geologic era to another, it is nearly constant during short periods and is distributed with approximate uniformity throughout all parts of the lower atmosphere. In these respects it differs widely from water-vapor, which enters and leaves the atmosphere with great freedom and varies in amount several hundreds per cent in different parts of even the lower atmosphere. While both CO_2 and H_2O in the air are absorbers and radiators and share these functions in common, their other differences place them in distinct classes. While CO_2 has some little power of absorbing the incoming solar rays, it is so little as to be negligible in a general analysis of this kind; only its ability to absorb and re-radiate a certain part of terrestrial radiation need be considered.

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[1] "Storage of heat" in this report is used only in the sense of the retention of *sensible* or true heat. It is not used in the sense of transformed heat, such as "latent heat" or "potential temperature," which are not strictly thermal at all.

Estimates of the total absorbing capacity of the CO_2 of the atmosphere have varied rather widely, but 14 per cent of the terrestrial radiation (Abbot and Fowle)[1] may be taken as a conservative figure. The points here urged are not especially affected by the closeness of this to perfect accuracy. It has been urged[2] that much less than the total amount of CO_2 in the air can absorb all the terrestrial radiation susceptible of absorption by CO_2 and that no additional amounts of CO_2 in the air would absorb a larger percentage. This seems to imply that the 14 per cent absorbed is all of the terrestrial radiation whose wave-lengths are of the class susceptible of absorption by CO_2; otherwise additional CO_2 would absorb them. As 14 per cent appears an entirely reasonable amount, this view is accepted as a present working basis. From this primary absorption a secondary series of absorptions and radiations take their origin. The total value of the thermal work of CO_2 in the atmosphere includes this secondary series of absorptions as well as the primary absorption.

On the assumption that there is more than enough CO_2 in the air to absorb all the wave-lengths in the terrestrial radiation susceptible of absorption by it, the first absorptions would obviously take place at levels below the upper limit of CO_2 and, if there were much more than enough CO_2, at levels comparatively near the earth's surface. If a column of 50 centimeters of pure CO_2 at mean temperature and pressure can completely absorb all terrestrial radiation that any amount of CO_2 can absorb, and if the CO_2 in the atmosphere is equivalent to a column of pure gas 250 centimeters high, or proportions of any such order as this, the first absorption would be complete at a low level in the atmosphere. The mean level of this first absorption is the mean from which the secondary series of radiations and absorptions start and thus determines their chances of prolonged action in the atmosphere, for the first set of the secondary series of radiations and absorptions is followed by still another set of radiations and absorptions, and so on indefinitely until all these secondary radiations escape from the atmosphere or are otherwise disposed of. All these radiations of CO_2 will have the CO_2 wave-lengths and be readily absorbed by other molecules of CO_2. The successive sets of radiations will presumably decline in thermal value as the repetition goes on, but the rate at which they will decline will depend on the amount of CO_2 (or other absorbent and radiator of these wave-lengths if there be such) in the atmosphere. To appreciate the full realities of the case, it is necessary to carry the analysis more into detail.

Since each of the molecules of CO_2 that absorbs terrestrial radiation re-radiates the energy thus acquired in all directions, these radiations encounter different contingencies in different directions. For a representative case, let a molecule be chosen that vibrates at the mean height of its class. The excess of molecules that were not able to take part in the absorption of terrestrial radiation of course lie mainly at high levels. Picture this representative molecule as at the center of an imaginary cube, so that its radiations will be tangibly and conveniently grouped according as they issue from one or another of its six sides. The one sixth of the radiation directed skyward will have the best chance of escape into outer space without encountering other molecules capable of absorbing it. Even if all the CO_2 in the atmosphere were engaged in the first absorption, a part of this sixth of the radiation would be absorbed, though the chances would be poor. But if the larger portion of the CO_2 were not involved in the first absorption but lay above, even this outward-going sixth would have little chance to escape a second absorption and the contingencies that lie beyond that.

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[1] Annals Astrophys. Obs. Smithsonian Inst., vol. II, p. 172 (1908).

[2] W. J. Humphrey, Physics of the air, p. 567 (1920).

One of the other sixths of the molecules' re-radiated energy would be directed earthward and would almost certainly either be absorbed by the molecules of CO_2 intervening between it and the earth—or by any other molecules capable of such absorption—or would reach the earth, be absorbed again, and start on a new career as new terrestrial radiation. The remaining four sixths would be radiated in a more or less horizontal direction and would penetrate much greater depths of air before reaching open outer space and would encounter correspondingly large chances of absorption. If there is more than enough CO_2 in a vertical section of the atmosphere to absorb all of this type of rays in the terrestrial radiation, there would certainly be much more than enough CO_2 in a tangential section. The total secondary absorption of this initial re-radiation would be relatively large.

But, as already observed, the secondary series does not end with this re-radiation. Every unit of energy absorbed in it starts a new radiation of like nature, and so absorption and re-radiation continue until all the thermal energy has escaped in some way. Perhaps the most piquant feature of the case lies in the quasi-paradoxical fact that the smaller the *proportion* of the CO_2 molecules required to make complete first absorption of the CO_2 class of wave-lengths the higher is the percentage of contingencies of secondary absorption and the greater the relative prolongation of the thermal activities of this class.

But two other factors are to be considered. The discussion has proceeded thus far on the standard assumption that the molecules of each gas absorb selectively only a certain set of wave-lengths, and that one gas does not do the work of another, at least so far as their distinctive work—selective absorption and emission—is concerned. It has been urged, however, that the vapor of water can absorb the same portion of the terrestrial radiation that CO_2 is known to absorb selectively, and may thus replace its work and destroy its importance as a climatic agency. Whatever may be true, or appear to be true, in the case of warm, fully saturated air on the very borders of precipitation or in its early stages, there is ground to question this claim when the vapor-content of the air is low, as when the air is very dry or very cold. But so far as this analysis is concerned, let this doubt be waived. Let it be assumed that the water-vapor can absorb and radiate precisely the same wave-lengths as carbon dioxide. This assumption implies reciprocity of action and carries the corollary that CO_2 can absorb and radiate the corresponding wave-lengths radiated by the water-vapor, and that the vapor radiates such wave-lengths because it absorbs them. This amounts to increasing by so much the thermal function usually assigned to the CO_2 alone. If there is only 14 per cent of the CO_2 class of vibrations in the terrestrial radiation, of course no more than 14 per cent will be absorbed by any amount of CO_2 or of H_2O vapor, so far as the first action of absorption and of bringing this energy into heating service in the air is concerned; but if the water-vapor is a real substitute for CO_2, it should *increase the value of the secondary series just as if it were so much additional* CO_2.

So far as the initial absorption is concerned, it will be a matter of chance whether a molecule of CO_2 or of H_2O first catches any given ray in its outgoing path. Complete absorption of so much as can be absorbed will obviously take place all the sooner and all the nearer the earth than if CO_2 alone did the work. Hence, the secondary series of absorptions and radiations will begin closer to the surface and be the more likely to be prolonged because of the greater depth of absorbents above. Thus, while the CO_2 will be anticipated in a part of the work of first absorption, it is merely a case of apparent suffering from competition, in which the heating service gets the benefit of two agencies instead of one. The carbon dioxide is not robbed of its function but merely forced to effect it in a different way.

Still another mode of prolonging the activity which starts in the form of CO_2 wave-length springs from the relations of CO_2 to the nitrogen group in the air. Each molecule of CO_2 which has been heated by absorption of terrestrial radiation is forced to collide with its neighbors several billion times a second, according to standard computations. The colliding molecules necessarily exchange energies. A part of the energy takes the form of translatory motion and is distributed so rapidly and intricately that no particular type or unit can be followed further. But it has become a factor in the temperature of the air and can not be radiated away until it has become a factor in the internal mechanism of an atom or molecule. It will suffice, therefore, to follow the energy that remains embodied in the atomic or molecular mechanism, for, notwithstanding their contribution to the common transitory activities, each molecule still has its own internal activities, and it is through these alone that radiation and related actions take place. The nature of the thermal exchange which occurs when a molecule of CO_2 collides with a molecule of nitrogen depends on which molecule has the higher temperature. In an average case near the earth's surface the molecule of CO_2 should be the warmer, for the processes that generate CO_2 are exothermal, such as the decay of vegetable matter, the respiration of animals, the combustion of fuel, volcanic action, etc. Carbon dioxide thus habitually enters the atmosphere with an excess of genetic heat, while it is likely to have at least as favorable contacts with the heated earth as nitrogen. As the air rises, the nitrogen group have no further earth contacts, but the CO_2 is constantly absorbing terrestrial radiation and should be warmer than the non-absorbers so long as the earth is a source of heating, which is the normal state. A part of the excess of heat of CO_2 is therefore conveyed to the molecules of the nitrogen group, and as these have little power of radiating this increment of heat away it is pocketed, as it were. Normally, its escape is delayed until it is withdrawn again by a radiating molecule or until some other of the limited and indirect means of escape available to this class becomes available. The molecules of the nitrogen group thus serve as temporary pockets, lockers, or reservoirs into which the CO_2 sends a part of the excess of heat it absorbs from the terrestrial radiation. Since the molecules of the nitrogen group vastly outnumber the molecules of CO_2, the presumption is that a large fraction of the excess of heat gained by the latter from terrestrial radiation will be conveyed by collisional action to the former and will be retained in thermal activity longer than if it had taken the secondary radiative courses sketched above.

While it is quite certain that the average molecule of CO_2 in the lower part of the atmosphere is warmer than the average molecule of nitrogen, the opposite contingency must be recognized. In the uppermost atmosphere the CO_2 may, indeed, habitually become the cooler, because it may there radiate outward more than it absorbs from below. This radiated portion, however, reenters the secondary series of absorptions and radiations sketched above, but, by hypothesis, high in the atmosphere, with good chances of early escape. In this case, the CO_2 draws on the heat stored in the nitrogen pockets or reservoirs and puts it again in the way of escape. Carbon dioxide may thus serve as a cooling agency. In the large view, its function is regulative, serving as a door of entrance into temporary storage for earth heat and of exit into the mechanism of escape for any excess of heat in the body of the atmosphere. But at the very low temperatures of the upper atmosphere the radiating power of CO_2 is low, since, according to Stefan's law, radiation is proportional to the fourth power of the absolute temperature.

Carbon dioxide is a "permanent" constituent of the atmosphere in the sense that it remains a gas under ordinary conditions and is distributed nearly uniformly in all latitudes and probably at all altitudes that much affect the lower climatic zone. When, however, geological eras are considered, it is subject to important fluctuations. One type arises from its effort to maintain equilibrium with many times its own amount in the ocean, partly in a free and partly in a loosely combined state. The very massiveness of this combination makes its fundamental changes slow. At the same time, this gives range and capacity, and to that extent fits it to play a part in climatic changes of the long-period type. A lowering of the temperature of the ocean of 21° C. in the vicinity of the freezing-point about doubles the amount of CO_2 required for equilibrium, and here is another source of variation of the long-period order. The extent to which CO_2 is consumed in the solution of limestone and other carbonates and in the formation of plant tissue is still another that rises to the geologic order. Its great capacity for combination is undoubtedly the reason why the quantity of CO_2 now left in the atmosphere is so small. The varying of the rate of combination as the land is elevated and extended, on the one hand, or as it is base-leveled and submerged on the other, must apparently lead to increases and diminutions of the free and potentially free CO_2 in the air and the ocean. These run hand in hand with the more profound geologic movements and give to this atmospheric factor a direct geologic relation. But it is itself dependent and hence an analysis of the whole complex combination is necessary to its evaluation.

CLIMATIC FUNCTIONS OF THE VARIABLE CONSTITUENT, WATER-VAPOR.

The third thermal factor in the atmosphere differs radically from the others in its variability, the rapidity of its changes, and the contrasts of its successive forms. The thermal effects of its entrance and exit are not less important than its thermal service while in the air. The variation of the amount of water-vapor in the air, from the low content in arid and frigid regions to oversaturation in the torrid tracts, is some hundreds per cent of its minimum. Water-vapor is perpetually being thrown into the air from the earth's surface by evaporation and is soon sent back by precipitation as liquid or solid. It runs rapidly through the gamut, solid-liquid-vapor-liquid-solid, or some part of it, with extraordinary changes of thermal properties. It therefore presents in itself a complex of thermal problems.

In coming into the atmosphere by evaporation much heat is abstracted from the surface and the basal air. The vapor thus enters the atmosphere at less than the mean temperature of its locality. It begins its work as a cooling agency. At this stage it contrasts strongly with CO_2, which usually comes into the atmosphere with an excess of heat.

After being brought into the atmosphere at thermal loss, water-vapor serves—for the short period it remains vapor—as a very effective absorbent of terrestrial radiation, a partial absorbent of solar radiation, and an effective radiator of its own heat. This is well recognized and much emphasized. The time-factors, however, are difficult to determine. If there are any careful estimates of the mean time between its evaporation and its condensation during which a molecule of water serves as vapor in the air, they are not known to the writer. A considerable portion of vapor rises rather directly from the evaporating surface to the clouds, and there rather promptly passes back to the liquid or solid state. Another portion remains much longer in the air as subsaturating moisture. A small residue persists under any natural conditions and seems to serve as though it were a permanent water-gas, but this part is doubtless merely a changing remnant, not a gas in which the individual molecules persist. However this may be, the mean lifetime of a molecule of H_2O as vapor is short, and so the thermal balance between the thermal cost of birth and the thermal recovery at death is a matter of moment. The amount of energy given out on condensation is equivalent to that made latent by evaporation, and such difference as there may be in effectiveness in heating the atmosphere is essentially the difference between thermal energy applied at the bottom of the atmosphere and that applied at levels higher up. As the principle is the same as in the case next to be considered, space will be saved by taking them together.

As already noted, water-vapor absorbs a minor fraction of the incoming solar rays but has greater capacity for absorbing outgoing rays. It is a fair presumption, then, that if water-vapor did not absorb energy from the solar rays as they come in, the vapor would catch the equivalent energy on its way out in the form of terrestrial radiation. The question then arises whether this ability to absorb incoming rays works to advantage in heating the climatic zone near the earth's surface. It is obvious that the first absorptions of the incoming rays would take place at higher levels on the average than the first absorptions of the outgoing terrestrial radiation. Hence, the secondary series of absorptions and radiations of the former would offer readier escape skyward than those of the latter and their active careers in the atmosphere be less prolonged and effective.

However, the main thermal work of water-vapor is the absorption of terrestrial radiation and what follows this. The first absorptions are near the earth's surface, from which the radiation starts, and the secondary series of absorptions and radiations start low in the atmosphere and hence have high chances of further absorptions. The secondary series takes much the same general courses and is subject to much the same incidental conditions as the secondary series of CO_2 already sketched, and these do not need repetition here. Such differences as exist are mainly those connected with the return of the water-vapor to the liquid or solid state. When the molecules of water-vapor have an excess of heat over the adjacent constituents, they feed into the thermal pockets offered by the nitrogen group, as in the case of CO_2, and likewise draw upon them and radiate heat away when their temperatures are lower. The molecules of the nitrogen group thus serve as temporary pockets for the heat absorbed by water-vapor also.

But the account of the water-factor does not close when the vapor passes back to droplets of water or floating ice crystals. The resulting clouds play an important part by throwing back into outer space about 70 per cent of the solar rays that fall upon them. There is some compensation, however, in the terrestrial rays they throw back toward the earth. The clouds are themselves absorbers and radiators. A part of the atmospheric vapor, when condensed, takes the form of ice crystals, which, after serving their functions in the air, form mantles of snow on the earth's surface that usually persist longer than the clouds and thus add much to the total reflection of the icy products of the vapor. All these factors are to be equated and charged against the account of water-vapor, for they are the offspring of the vapor. According to Dines's estimate, about one-half of the energy of the solar rays is reflected and takes no part in the heating of either the earth or the atmosphere. This probably includes the scattering of light by the molecules of the atmosphere and by dust suspended in it; but discounting liberally for this, there remains a heavy charge to be carried to the account of water-vapor because of the reflection caused by its products.

The falling of rain, hail, and snow through the atmosphere has a cooling effect, which, though apparently a minor matter, must be added to the adverse side of the thermal account of water-vapor.

In view of these heavy items on the debit side, the question naturally arises whether the climate of the earth would not be warmer than it is if there were no water on its surface and no water-vapor in its atmosphere. The question, however, is premature at this point, for the water in the atmosphere is inseparably connected with that of the hydrosphere, and the climatic influence of this should be considered as well as that of the land surface.

THE THERMAL FUNCTION OF THE LAND SURFACE.

Thus far, for convenience, the surface of the earth has been treated as though it were a unit absorbing insolation and either imparting it to the atmosphere directly by contact or radiating it skyward subject to further absorptions and radiations or to escape into outer space. But the land surface and the water bodies, especially the ocean, play very different parts, which involve very different time-factors; indeed, in the oceanic function, the time-factor rises to climacteric importance.

The land has relatively small competency to detain heat, for it is readily taken in and readily given out, both by contact and by radiation. The penetration is relatively slight and the capacity for thermal storage small. The ordinary seasonal variations of temperature cease to be appreciable at very moderate depths. Even such cumulative effects as have been inherited from the last glacial period seem to be inappreciable below 1,000 or 1,200 feet.[1]

THE THERMAL STORAGE OF THE OCEAN.

The case is radically different, however, with the ocean, in several vital respects. The surface of water reflects more of the solar rays than does the surface of the land when neither is covered with snow or ice. There is also a deeper penetration of the rays retained and a more distributive effect.

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[1] The degrees of extension and of relief of the land are more remotely very important climatic factors, but are here excluded for lack of space, though they have time-functions of moment.

There is also greater evaporation. Taken together, these give to the mean surficial influence of the ocean a cooling rather than a warming influence.[1]

But when the accumulation and retention of heat within the great body of the ocean, and their bearings on climatic eras of the geologic order, are considered, the case assumes an aspect of a high order of importance.

The surface of the ocean is about three times that of the land, but the oceanic mass subject to climatic changes is probably twenty or thirty times that of the surface film of the land which partakes effectively in climatic changes. Besides, the specific heat of water is about five times that of average soil or rock. These differences give to the ocean a capacity for storing heat which is a high multiple of that of the land or that of the atmosphere. It is a thermal reservoir of vast competence. The atmosphere serves as a door of entrance into this and exit from it, much as the nitrogen group, in a smaller way, forms a reservoir to which carbon dioxide and water-vapor serve as doors of entrance and exit.

The very massiveness of the ocean and its exceptional capacity for heat make its responses to external changes in the heating process very slow and the time-factor rises to special importance.

The three well-known agencies of oceanic circulation give rise to cycles of three orders of time values: (1) cycles due to propulsion by wind; (2) cycles due to heating in low latitudes and to cooling in high latitudes; (3)cycles due to increase of salinity in zones of high evaporation and to freshening in zones of high precipitation.

(1) The first is a direct atmospheric contribution and is effective chiefly in giving surficial and regional currents with incidental upwellings and sinkings. The periods of these cycles are long relative to those of the atmospheric cycles, but short relative to those of the deep-sea circulation.

(2) The cycles due to heating in low latitudes and cooling in high latitudes, if they were permitted to work alone, would give rise to vertical circulation involving a surficial and a deep-sea component. Its periods would quite certainly be much longer than the preceding, but as the case is purely hypothetical this need not be urged.

(3) Cycles due solely to increase of salinity in areas of descending air, and consequent evaporation, cooperating with freshening in areas of ascending air and precipitation. If this couplet could act alone, its period would also be long.

The actual deep-sea circulation is the joint product of temperature differences and salinity differences acting as basal agencies, the wind contributing a surficial influence. Since circulation is an effort to secure equilibrium between disturbing causes, this degree of complexity of causes prolongs the effort and obscures the result, but gives it all the more climatic significance, for it is nature's correlation between the two greatest of the atmosphere's dynamic factors, differences in latitudinal heating and in vertical heating, both expressing themselves in part by the latitudinal winds and by vertical circulation of the atmosphere, which actuates evaporation and condensation.

The single method thus far proposed for the measurement of the cycle of this complex circulation rests upon the rate at which the combination of icy cold and highly saline water—of the type that fills the abyssal basins of the ocean—is formed in the polar regions. This is theoretically correlated with an atmospheric cycle of carbon dioxide, and subordinately of oxygen, for the assigned formation of the abyssal type of cold saline water is a side product of freezing and involves also the concentration of CO_2. The low temperature gives the power to hold about a double portion of dissolved CO_2.

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[1] A venerable climatic fallacy, Jour. Geol., vol. xxxi, pp. 179–191 (April-May 1923).

Starting with the warm oceanic water—which fossilized marine life implies for the greater part of geologic time in the polar as well as other basins—the progressive double charging of the ocean waters with CO_2 must have depleted the atmosphere. The process of depletion is assumed to have continued until the first charged water began to come to the surface in low latitudes and give up its supercharge because of high temperature. Meanwhile the polar charging is assumed to have grown less effective because of partial exhaustion of the atmospheric supply, which, however, would begin to be measurably restored when the increased output in low latitudes made itself felt. Thus, a cyclic atmospheric effect is assumed to have been superposed on the filling of the abyssal basins with ice-cold saline waters as an incident of freezing in the polar basins.

A paper has been published during the year giving in much detail the assigned method by which the cold saline abyssal waters are formed, and this carries the basis for a rough estimate of the time required for a single filling of the abyssal basins with their characteristic water. Preliminary results indicate that the period is not likely to be less than that of a glacial-interglacial epoch. The cycles of greatest length and of the highest order of importance, geologically, are assigned to the contests for mastery between the two fundamental systems of deep-sea circulation, the battle between low temperature and salinity for the mastery of the abyssal basins. The evidence of changes of deep-sea dominance rests on the following basis:

At present the deep-sea basins are unquestionably under the control of polar influence. In these regions waters of rather high salinity and distinctly low temperature are generated and creep slowly into the abyssal basins of low latitudes and there gradually rise and displace lighter waters. In the very arid regions, saline waters are formed by evaporation and descend to depths of 2,000 meters, more or less, contesting the complete dominance of the polar waters. The present struggle for mastery thus lies in the middle and upper horizons of the ocean. The trend of the contest at present is unknown, but there can be no doubt that the polar elements have dominated since the beginning of Pleistocene glaciation. So, too, there is little reason to doubt that during the earlier periods of glaciation of the Pleistocene type, and still less during the periods of glaciation on the borders of the tropical zone, similar ice-cold saline waters filled the abyssal depths and dominated the whole circulation. But, on the other hand, there were still longer periods in which the fossilized marine life seems to indicate that warm seas prevailed in the high latitudes and in all other latitudes, so far as known. This evidence seems to exclude the hypothesis of such icy dominance from lack of the requisite generating areas. It seems a logical conclusion that saline density generated in low latitudes then held the mastery and that the warm dense waters creeping to the polar regions gave them the benefit of a stupendous natural water-heating system. Under this interpretation, the time-factors of such climatic alternations rise to the grade of geologic eras.

Two papers bearing on this larger and strictly geological phase of the time element in the climatic problem have been published during the year.[1]

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[1] A venerable climatic fallacy, Jour. Geol., vol. XXXI, pp. 179–191 (April-May 1923). Significant ameliorations of present Arctic climates, Jour. Geol., vol. XXXI, pp. 376–406.

HISTORY.

James, Herman G., University of Texas, Austin, Texas. *Preparation of a monographic study of the government of Brazil.*

In continuation of a plan for various studies of the governments of South American Republics, the Institution having already issued a volume entitled *Federal System of the Argentine Republic,* by Dr. L. S. Rowe, Dr. James went to Brazil in June 1922 for the purpose of undertaking, at first hand, a study of the constitutional government of that country. He was successful in making desirable contacts with Brazilian officials and in obtaining access to all available works on the constitutional history and law of Brazil. He furthermore had the advantage of submitting his completed manuscript to Dr. Araujo Castro, one of the foremost authorities on Brazilian public law, and of discussing with him various aspects of his treatise.

HISTORY OF SCIENCE.

Sarton, George, Cambridge, Massachusetts. *Associate in the history of science.* (For previous reports see Year Books Nos. 18–21.)

The present (fifth) report covers from Sept. 1, 1922, to Aug. 31, 1923.

1. *Introduction to the History and Philosophy of Science.*—The greatest part of my time is devoted to the preparation of this introduction. I have now reached the fourteenth century, but I had to spend considerable time during the last year in correcting and completing previous notes. At this time I may be permitted to review what has been done. I have written 1,248 notes (ranging from a few hundred to many thousand words) dealing with the most prominent men of science and scholars and the most significant anonymous works down to the end of the thirteenth century.[1] These 1,248 scientists may be divided into four main groups according to the languages which they used: (1) Greek, Syriac, Armenian, etc., corresponding to the ancient Greek world and to Eastern Christendom, 362; (2) Latin and European vernaculars, corresponding to Western Christendom, 373; (3) Hebrew, Aramaic, Arabic, Persian, corresponding to Israel and Islam, 324; (4) Sanskrit, Tibetan, Chinese, and Japanese, corresponding to India, Central Asia, and the Far East, 189.

Some readers may be surprised that the numbers relative to the first three divisions are very close to one another (362, 373, 324) and that the one relative to the fourth, 189, is not so distant from the others as they might have thought. This will help them to realize that the traditions bequeathed by classical antiquity do not by any means form the whole of our intellectual heritage.

The compass of my investigations is well illustrated by the two annexed diagrams. In both of them, the abscissas indicate successive centuries, from the ninth before Christ to the thirteenth of our era, while the ordinates indicate numbers of scientists. These diagrams represent the progress of thought, but only to a certain extent, because the number of great scientists and scholars flourishing at any period is but one indication among others of its intellectual activity. The importance of some of these scientists is immeasurably greater than that of others. If it were possible to give them definite weights or coefficients before adding them up, the parts of the curve relative to ancient Greece, for example, would be much higher. Besides, the number of scientists tended naturally to increase throughout the ages, irrespective of the progress of science, together with the area of the civilized world.

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[1] I have not taken into account my notes on the fourteenth century because my study of that century is not yet finished.

The diagrams should be considered qualitatively rather than quantitatively. The curves aid one to visualize the amount of scientific activity accomplished at different periods by different provinces of mankind. For example, figure 1 gives one a good idea of the relative importance of East and West. One sees that down to the sixth century the West was preponderant, but that, on the contrary, from the seventh to the eleventh century the higher destiny of mankind was fulfilled mainly by Eastern peoples. Figure 2 enables one to appreciate the relative contributions of the four groups of peoples above mentioned. Thus, one notes that Greek influence was paramount down to the seventh century; then for one century, the Hindu and Chinese; and from the eighth to the eleventh century, and to an astounding extent, the Muslim. This makes it clear why knowledge of Arabic is as essential for understanding mediæval thought as knowledge of Latin and Greek. Indeed, it is indispensable for a deeper study of the eighth to eleventh centuries. After the eleventh century, Western Christendom has been the main leader.

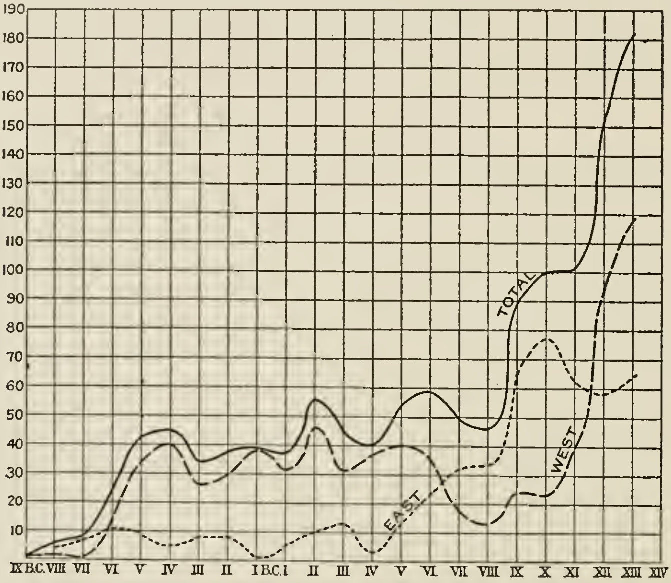

FIG. 1.—Progress of thought from ninth century B. C. to thirteenth century of our era. Of the three curves, one represents the total number of prominent scientists and scholars, others the partial totals relative respectively to East and West.

2. *The Publication of Isis.*—The fact that the history of science is not yet a recognized subject of study, even as, say, the history of art or the history of religion, causes the many papers devoted to it to be scattered among an exceedingly large number of periodicals—not simply among the almost innumerable journals of science, but among journals of history, literature, philology, art, orientalism, etc. Yet it is essential for the writing of my Introduction that I should have ready access to these papers; it is equally essential that I should keep in touch with the scholars who approach our field of study from whatever angle. All this is brought about by my editing

of *Isis*, for many books, papers, and private communications are sent to the Editor of *Isis* which would not be sent to me personally.

During the past year I have edited two numbers of *Isis*, forming, respectively, the end of volume 4 (pp. 455–654) and beginning of vol. 5 (pp. 1–324). They contain 11 papers, 11 shorter communications, 76 reviews, and 1,856 bibliographic notes. Some of these notes have been contributed by F. E. Brasch (Washington, D. C.), A. K. Coomaraswamy (Boston), L. Guinet (Brussels), L. C. Karpinski (Ann Arbor), P. Masson-Oursel (Paris), J. Ruska (Heidelberg), C. Schoy (Essen), H. Wieleitner (Augsburg).

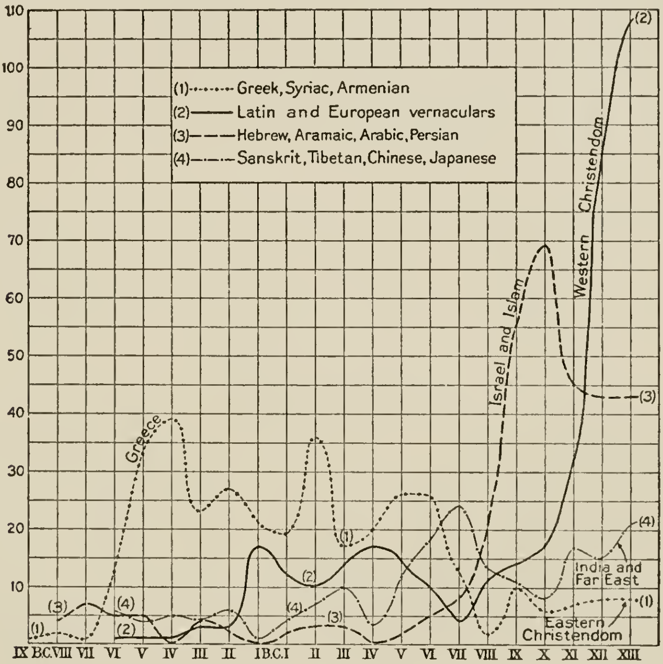

FIG. 2.—Relative progress of thought among the people speaking: (1) Greek, Syriac, Armenian; (2) Latin and European vernaculars; (3) Hebrew, Aramaic, Arabic, Persian; (4) Sanskrit, Tibetan, Chinese, Japanese.

3. *The New Humanism.*—My efforts to advance the study of the History of Science and to promote the New Humanism are naturally convergent. The New Humanism aims at reconciling the classical with the scientific ideals, and is best accomplished by approaching science itself from an historical point of view, and considering not simply its latest stage but the whole of its development. The sources of knowledge can be reduced to two: nature and history. Either is necessary, neither is sufficient. Knowledge, however, is one. The New Humanism is based upon two correlative notions, *unity of knowledge* and *unity of mankind*, both of which are inductively established by the historian of science.

4. *Lectures.*—I delivered one lecture at the Wesleyan University in Middletown, Connecticut, and a course of 43 lectures at Harvard University. The preparation of this course, dealing with the history of science in the eighteenth and nineteenth centuries, took considerably more time than I had foreseen. It was attended by fifteen students.

MATHEMATICS.

Morley, Frank, Johns Hopkins University, Baltimore, Maryland. *Application of Cremona groups to the solution of algebraic equations.* (For previous reports see Year Books Nos. 9–17, 19–21.)

The investigation of the equation of the eighth degree—the problem proposed for the current year to the Carnegie Institution—has reached a satisfactory stage of completeness. The detailed treatment of this case, with constant thought in regard to the possibilities of extension to equations of any even degree, has required the development of some new modes of approach and has led to some rather unexpected results. Thus, it appears that the generalized Weddle surface is a more convenient field for the allied hyperelliptic functions than the generalized Kummer surface, which is not true of the sextic equation. One unlooked-for result is the occurrence of linear relations among the hyperelliptic theta functions of order two and genus $p2 \overline{>} 4$ which do not exist in general.

A sketch of these researches will be made in an address before the joint meeting at Cincinnati of the American Mathematical Society, the American Mathematical Association, and Section A of the American Association for the Advancement of Science. This sketch will appear in the Bulletin of the Mathematical Society. A fuller account will be prepared for publication elsewhere.

METEOROLOGY.

Bjerknes, V., Bergen, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics in practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5–21.)

The last four reports have been devoted entirely to phenomena connected with atmospheric discontinuities, which give the key to theoretical understanding and practically forecast phenomena of the weather. During the current year the investigation of these discontinuities and their disturbances has been continued along both empirical and theoretical lines.

Mr. J. Bjerknes has been working in Switzerland this year, where he has had access to the important observations from the high stations in the Alps. He has taken up a detailed examination of different typical outbreaks of polar air, which inundated the greater part of Europe, including even the highest summits of the Alps, and studied the weather phenomena connected with the progressive advance of the cold front. This investigation has confirmed and completed the general conclusions which had been drawn in a more summary way from the study of the Norwegian daily weather maps. This work has not yet been accomplished, but when published will bring the final demonstration of many results which we have hitherto been able only to enunciate without demonstration.

A general view of the central theoretical problems of dynamic meteorology after the latest empirical discoveries has been given by V. Bjerknes in his paper "Dynamics of the circular vortex, with application to atmospheric vortex and wave-motion" (see Year Book No. 20). The problems may be stated thus: (1) To determine the condition of equilibrium of the atmospheric surfaces of discontinuity. (2) To examine the stability or instability of this equilibrium and the laws of the disturbances originating in and propagating along these surfaces.

Problem (1) has already been solved to a certain extent by Helmholtz and Margules.

Problem (2) demands the development of a general view, of which the theory of liquid boundary waves is the simplest example. This problem may therefore be solved by successive generalizations of this simplest wave problem, which is too narrow, especially in the following three respects: that the fluid strata above and below the boundary surface have generally been supposed to be incompressible; secondly, that these strata have generally been supposed to have no motion in horizontal directions; and thirdly, that the period of the waves has been supposed to be so short that the influence of the earth's rotation becomes insignificant. Three corresponding generalizations of the elementary wave theory will therefore be of fundamental importance, namely:

(1) To take into consideration the compressibility of the fluid strata.

(2) Retaining the compressibility, to take into consideration the motion of the strata in horizontal directions.

(3) Retaining the compressibility and the horizontal motion of the strata, to take into consideration the influence of the earth's rotation upon the waves.

The solution of problems (1) and (2) has been found in satisfactory generality, i. e., for waves of the "long" type (wave-lengths great compared with depth of the strata in which they propagate). The results obtained are of great simplicity.

A paper concerning problem (1) is in print and another paper dealing with problem (2) is being prepared.

Certain integrals of the hydrodynamic equations showing the influence of the earth's rotation upon wave-motion have also been found. These solutions make evident a marked difference in the character of the waves according to whether their period is smaller or greater than that of a revolution in the circle of inertia, i. e., smaller or greater than 15 hours at the latitude of 60°. Below this limit these solutions give waves of the permanent type propagating with invariable amplitudes, while above the limit these waves propagate with exponentially increasing amplitudes, indicating instability of the surface of discontinuity for disturbances of this period and a corresponding spontaneous formation of the waves. These solutions are, however, not of sufficient generality to be immediately applied to the cyclonic waves, but they seem to indicate that the formation of cyclones may be a spontaneous process. The entire clearing up of this question can be gained, however, only when more general integrals of the hydrodynamic equations have been found.

NUTRITION.

Osborne, T. B., and L. B. Mendel, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3–21.)

In our last report we referred to studies which were in progress on the water-soluble constituents of alfalfa and which we hoped might ultimately lead to a better understanding of the chemistry of the cell and more specifically of the chemical make-up of this important forage plant.

Although progress in this difficult field of investigation has necessarily been slow, the results thus far obtained have been such as to impress us with the great importance of the problems awaiting solution. Until far more is learned of the chemical constituents of the cell than is at present known, plant physiology and plant physics will have a very inadequate foundation. A study of the literature shows how limited this knowledge is, for it is chiefly confined to an enumeration of chemical substances which have been obtained from many species of plants, very little being found which enables one to form a conception of the relations which these bear to one another or to the metabolic processes incident to the life of the plant. However much impressed one may be by the paucity of the information obtainable from the literature, attempts to deal with the mixture of substances as they occur in the plant-juice impress one even more by showing how small a part of these are made up of already-identified substances. One can not fail to recognize that here is an almost unexplored field for future investigations.

Naturally, in dealing with such a complex mixture of inorganic substances, which in the past have received very little attention from chemists, progress has been slow. Nevertheless, data have been secured which we believe to be essential to the development of methods which are needed before the individual constituents can be isolated and identified.

In our last report we dealt with the proportion of different forms of nitrogen present in solution both before and after hydrolysis. We there stated that from the basic constituents precipitated by phosphotungstic acid after hydrolysis no arginine, histidine, or lysine could be isolated. As relatively small quantities of the juice were used for these experiments, we have since repeated them, using much larger quantities.

The filtrate from the precipitate produced by adding 53 per cent, by weight, of alcohol to 3,415 c.c. of the juice of the alfalfa plant was concentrated, boiled with 25 per cent of sulphuric acid for 12 hours, and the basic products of hydrolysis precipitated with phosphotungstic acid. By employing Kossel's method for determining the basic amino acids produced by the hydrolysis of proteins we found that the silver-baryta precipitate yielded arginine containing nitrogen equal to 3.6 per cent of the nitrogen present in the filtrate from the precipitate from the 53 per cent alcohol precipitate. This was identified as the picrolonate.

Another substance yielding a crystalline hydrochloride, which did not give the reaction with diazo-benzene sulphonic acid characteristic of histidine, formed most of the precipitate produced by $HgSO_4$. When converted into the picrate, this melted sharply at 298°. If histidine is present among the bases, its proportion must be very small. The amount of the above substance was not enough to permit of its identification. It contained nitrogen equal to 2.2 per cent of the total nitrogen of the original solution. Since 90 per cent of the nitrogen of the second silver-baryta precipitate was recovered in the arginine picrolonate, it is evident that besides the unidentified base obtained from the $HgSO_4$ precipitate and arginine there is little, if anything else, among the products of hydrolysis thus precipitable by silver.

The filtrate from the silver-baryta precipitate, which should contain lysine, was found to contain also stachydrine in much larger proportion than lysine. The nitrogen in the stachydrine was equal to 5.4 per cent of the nitrogen in the filtrate from the 53 per cent alcohol precipitate and that of the lysine to 1.16 per cent. These bases were separated by means of $HgCl_2$, the fraction obtained at acid reaction consisting almost wholly of the mercury salt of stachydrine, while that precipitated at alkaline reaction contained the mercury compound of lysine. Both of these substances were identified as picrates.

The presence of stachydrine thus established confirms Steenbock's early discovery of this betaine among the constituents extracted by water from alfalfa hay. Whether all of the stachydrine found by us exists in the free state in alfalfa-juice is not demonstrated by our experiments. Steenbock's work indicates that at least a part of this base is free, unless all that he isolated was liberated by enzymes during curing of the hay or its extraction by water.

The fact that practically all of the nitrogen precipitated by $HgCl_2$ at slight acid reaction was identified as stachydrine shows that significant quantities of other bases thus precipitable were not present.

These results show that, so far as basic substances are concerned, the greater part of the products of hydrolysis of the constituents of the alfalfa-juice are quite unlike the products of hydrolysis of protein, and that Van Slyke's method, which was devised to determine the relative proportions of the amino acids yielded by proteins, gives results which are wholly misleading when applied to green plants.

The attempts to isolate the apparently abundant coloring matters which can be extracted with amyl or butyl alcohol from the hydrolyzed juice of the alfalfa-plant showed that a relatively large proportion of nitrogenous substances is simultaneously extracted by these alcohols from the strongly acid solutions. It seemed probable that this nitrogen might belong largely to hydrochlorides of amino acids, but as yet aspartic acid is the only amino acid which we have been able to identify among these nitrogenous substances. Experience has convinced us that precipitation with metallic salts will enable us to obtain fractions from which products of hydrolysis may be obtained, and also to gain an insight into the possible origin and relationships of the various products whose presence has been revealed by our previous work with the alfalfa-juice. Although marked progress in this direction has been made, it is too soon to venture definite statements concerning the data thus far obtained. In dealing with such a complicated mixture we feel that a detailed statement concerning this part of our work will, at the present time, contribute too little that is definite to justify its publication.

During the past year we have been fortunate to have the cooperation of Dr. A. C. Chibnall, whose previous experience in studying the proteins of the leaf with Professor S. B. Schryver, of London, was of value in supplementing our own experience with alfalfa.

Dr. Chibnall has devoted himself to completing work begun in England and has furthermore demonstrated the possibility of obtaining the contents of the vacuole of the cells of the spinach-leaf uncontaminated with the protoplasmic constituents. Since this process can be applied on a large scale, it should be possible to learn far more about the chemical make-up of the constituents of the vacuole than we now know. It appears possible, also, after the contents of the vacuole have been removed, to extract the protoplasm as a colloidal solution fit for chemical examination. Dr. Chibnall expects to continue these investigations during the coming year.

During the past year Dr. Vickery has continued his study of the rate of hydrolysis of gliadin and has directed his attention especially to an insoluble product which separates from the solution during this process. This product might be either a resistant fraction, which for many years chemists have considered to be characteristic of the protein molecule, or it might be gliadin from which only the amide nitrogen had been eliminated. A comparison of curves showing the rate of hydrolysis of this product and that of gliadin revealed no marked differences, thus demonstrating that gliadin, at least, does not contain a resistant moiety.

With respect to its content of arginine, lysine, and the non-amino nitrogen of the filtrate from the basic amino acids, which is probably very largely proline nitrogen, the insoluble product differs in constitution from that calculated for gliadin from which amide nitrogen alone has been removed. Moreover, when prepared under the conditions detailed above, this insoluble fraction contains all the lysine of the original gliadin. In its production, therefore, hydrolysis of peptide bindings as well as of amide bindings has played a part. Efforts to remove only amide nitrogen from gliadin, without simultaneously rupturing peptide bonds, have been unsuccessful.

In connection with all studies on the rôle of protein as a component of the dietary it has become desirable to prepare rations in which the protein under consideration shall form as far as possible the sole source of nitrogen in the dietary. In the past the fact that the commonly used sources of vitamine B contain more or less nitrogenous material, some of which is protein, has led to more or less justifiable criticism of such studies. The vitamine component thus introduces an added variable into the experiment so far as the protein factors are concerned. It was a helpful step in the direction of progress when it became possible to use, as a source of vitamine B, a fraction of yeast extract which no longer gives the ordinary tests for proteins. We have accordingly found it highly advantageous to make use of this "concentrate" in our newer studies. Before engaging in any extensive use of the concentrate we have made an investigation of the relation of the size of the animal at different stages of development to the quantity of the yeast fraction required to secure satisfactory growth on diets of the same composition. Recently we reported similar experiments with dried whole yeast as a source of vitamine B for rats. Although the absolute quantity of dried yeast required increased with the augmented size of the animal, it appeared that the daily requisite per 100 grams of body-weight approximated what is contained in 50 to 60 mg. of the dried yeast used by us.

The experiments with the yeast concentrate first prepared by Osborne and Wakeman and described in earlier reports are in progress. They already indicate that as the body increases in size larger absolute amounts of the vitamine-bearing product are necessary for adequate nutrition. Larger animals may even decline in weight on a daily dosage which suffices for adequate growth for small animals.

In view of the widespread use of eggs in the dietary of man and the popular belief that these products are especially rich in vitamines, so that they are frequently classed with milk in such generalizations, we have lately recorded experiences which we have incidentally gained in recent years. By extraction of egg yolk with water it is possible to secure a product comparatively rich in vitamine B, the daily dose required for a 100-gram rat being considerably less than that of the most potent dried yeast hitherto examined. The content of the entire egg-yolk, however, in vitamine B is not large, a daily intake of at least 1.5 grams of the fresh yolk being required when it furnishes the sole source of vitamine B to a 100-gram rat. The whole egg is accordingly not exceptionally rich in vitamine B when contrasted with other foods already investigated. Judged by the comparative trials on rats, the average sized hen's egg is equivalent in vitamine B potency to about 150 c.c. of cow's milk; or a quart of milk and six or seven whole eggs of the average sort have an approximately equivalent vitamine-B value.

The problem of the origin and storage of vitamines in the animal body is one which has been much debated in recent years. There is a widespread and well-founded impression that these food factors are not synthesized in the animal organism but are derived exclusively from plant sources. It has been debated whether, when an animal is maintained for some time on a diet devoid of one or another of the vitamines, its organism becomes depleted in any way with respect to vitamines which may have been stored therein. In order to secure some evidence regarding this, we have compared the content of vitamine B in comparable quantities of liver tissue obtained from rats which have been respectively fed on diets devoid of vitamine B and on a mixed diet demonstrably rich therein. The outcome has been very striking; for example, whereas a dose of 200 mg. of the dried liver tissue of adequately fed rats suffices as a source of vitamine B for a 100-gram rat subsisting on a diet adequate in every respect except this vitamine, the same amount of hepatic tissue from animals which have been deprived of vitamine B for some time is entirely inadequate. Obviously, therefore, when vitamine B is furnished in insufficient abundance with the diet, whatever store thereof may be in the organism becomes destroyed or depleted in some way. Thus far our observations have been confined to a single storage organ—the liver. It will require further extensive investigations to ascertain whether and to what extent similar phenomena of storage and depletion occur in other tissues of the body. The answer to such inquiries may throw some light upon the possible rôle of vitamine B in metabolic processes.

We have lately repeated our earlier demonstration that rats can grow to considerable size on diets consisting of nine-tenths or more of protein, provided they receive a suitable supply of vitamines A and B as well as of inorganic salts. Both casein and washed meat were used as the sources of protein. Similar tests have since been made with rations containing about 75 per cent of protein in the diet. It seemed unlikely that rations on which young rats grew from 60 to 260 grams could be extremely harmful to the organism. However, there is a widespread popular belief that a high-protein diet in man is a renal irritant; and the production of arteriosclerosis in rabbits has been attributed to "diets containing 27 and 36 per cent of protein derived chiefly from beef." For this reason it seemed desirable to have some of the tissues of rats growing on our diets very high in protein subjected to histological examination. This has been secured through the cooperation of Professor E. A. Park and his collaborators at the Yale University School of Medicine in a preliminary study of some of the animals grown on the high-protein diets. The only striking change was found in the kidneys, which were greatly hypertrophied, the average weight being almost twice that of the control animals and their size about one-third greater. Microscopic examination showed no changes of an inflammatory or degenerative nature. The exact histological condition of the kidneys and of the other organs will be reported subsequently. Hypertrophy of the kidneys existed without hypertrophy of the heart. The ratio of the weight of the heart as well as of the liver to the body-weight was about the same in the animals fed the high-protein diets as in the control animals. The ratio of the weight of the kidneys to the body-weight in the animals on the high-protein diets was, on the average, almost double that of the control animals. The hypertrophy occurred whether the protein used was of animal or vegetable origin or was rich or poor in phosphorus.

The animals on such diets were poorly or, at best, only moderately well nourished. The subcutaneous fat was scant and the skin adherent. There was some fat in the abdominal cavity and in certain animals it was fairly plentiful, but in none was it so abundant as in the control animals. In some animals the lungs showed the infection so commonly seen in the domestic rat. The thymus was invariably atrophied. The heart was normal. The spleen varied greatly in size. In some rats it was large, in others normal, and in others atrophic. The liver presented no gross abnormalities. The testes in some of the animals were normal in size; in others they were exceedingly atrophic.

The cause of the renal hypertrophy just described is of physiological interest. Is it a functional hypertrophy due to the necessity of excreting unusually large quantities of the products of protein breakdown? Some of the questions here involved are being considered by inducing "overwork" on the part of the kidneys through the necessity of excreting large quantities of other produ cts than the nitrogenous catabolites. The effects of eliminating large quantities of phosphate belong in this category.

Through the continued cooperation of Dr. A. M. Yudkin the pathology of the ophthalmia which we described long ago, and which occurs as the result of deficiency of the vitamine A in the diet, has been continued. His efforts are being directed to a more detailed study of the incipient stages of the pathological changes and likewise to the extent and character of the recovery when sources of the vitamine are given to the affected animals. In this connection we have incidentally observed, in harmony with the reports of others, that cod-liver oil through which oxygen has been bubbled for a considerable time, while the fat was kept warm, loses its vitamine A potency judged by the capacity to cure the ophthalmia. Mere heating of vitamine-A-bearing products does not necessarily destroy the potency, for we have lately found alfalfa dried in a current of air to retain its curative property.

We have collaborated with Professor Park and his associates at the Yale School of Medicine in investigations of the histological changes taking place in the skeleton and other structures under conditions of diet in which one or more known deficiencies occur. Many studies of this charcater have been reported within the past few years. Not a few of these, however, are of doubtful value for the elucidation of the etiology of abnormalities in bone development and tissue growth because of the undue number of variables which have been introduced by the somewhat miscellaneous character of the foods. Our effort has been directed primarily to secure observations under as carefully controlled conditions of feeding as the circumstances and limitations of our present knowledge will permit. Therefore, in many cases instead of using foods as they occur naturally we have made use of mixtures of isolated food materials. The very large number of experiments already undertaken point to the complexity of the problem of tissue growth, particularly as it is exemplified in the bones. Various factors doubtless interplay in ways that have not hitherto been appreciated or taken into account. For example, seemingly slight differences in the diet may lead to quite unlike pictures of structural abnormalities, which will require extended careful analysis before any more comprehensive generalizations can be drawn. We propose to continue these experiments for some time; they include a consideration of some of the antirachitic substances.

The studies on the failure of many animals to breed on rations consisting of purified proteins, fat, carbohydrate, and salt mixtures, together with fats bearing vitamine A and yeast as a source of vitamine B, upon which they have grown splendidly, are being continued. Mr. K. E. Mason, working in Professor Harrison's laboratory at Yale University, has found changes in the gonads of the male in many instances. These can be averted or altered by certain additions to the diet. For the present, the foremost emphasis is being placed upon the determination of precisely the type of structural alterations that present themselves in the testes. Later, when these are more clearly understood and the conditions which give rise to the defects and their repair are better ascertained, it may be more profitable to direct further attention to the possible nature of the essential dietary components, without which the developmental conditions essential for reproduction do not seem to be properly established.

The failures to breed thus far observed in the seemingly well-nourished animals are apparently not due merely to a shortage of vitamine A or vitamine B in the diet. At any rate on the so-called synthetic rations, neither cod-liver oil nor yeasts, which respectively furnish liberal quantities of the vitamines referred to, have sufficed to insure fertility. "Fresh" food, as it is provided in green vegetables, fruits, etc., is by no means indispensable for this function. We have prepared a simple mixture of *dried* materials (consisting of alfalfa-meal, casein, meat scrap, "red dog" flour, and salt) which furnishes all the dietary components essential for maintenance, growth, reproduction, and lactation in rats. We hope that the attempts to devise a simple inexpensive mixture of this sort, in which we have been engaged for some time, will not be without value to those who use the rat as a laboratory animal.

The physiological functions of the inorganic components of the diet have not received the attention which the great importance of the subject demands.

In earlier studies we have pointed out to what extent limitations with respect to a single ion such as calcium, potassium, phosphorus, etc., may affect the nutritive well-being as evidenced by changes in body-weight. The quantitative aspects of the subject demand further consideration, particularly in the light of current studies on rickets and other bone disorders associated with dietary deficiencies. Preliminary results which we have already secured by limiting the total intake of a qualitatively satisfactory salt mixture, in an otherwise adequate diet, point to the possibility of producing more or less permanent defects from which recovery is not as readily possible by increasing the quantity of the minimum component as seems to be the case with respect to other dietary factors. Usually when an animal fails to grow normally because of a shortage of protein, for example, in an otherwise adequate ration, an increased supply of good protein will bring about prompt recovery. On the other hand, in experiments in which the total admixture of our satisfactory salt mixture has been limited to 0.5 or even 1 per cent of a food such as we have been accustomed to employ, and the animals have failed to grow well because of this limitation, complete recovery and satisfactory growth have as yet in no case ensued when the percentage of salt mixture has been increased to the conventional proportions. Why restoration is less readily accomplished by feeding a suitable ration after an animal has been limited with reference to its intake of inorganic nutrients alone deserves careful consideration. The possibilities of physiological damage in this way may be not inconsiderable in the case of man, who is gradually becoming accustomed to refinement and alteration in his natural foods, and ordinarily takes no account of the possible limitations of the inorganic ingredients of his diet.

PALÆOGRAPHY.

Lowe, E. A., Oxford, England. *Associate in palæography.* (For previous reports see Year Books 9–16, 19–21.)

During the past year considerable advance has been made in the investigation of both the uncial and the half-uncial script. The exhaustive material made available by the collection of negatives renders it possible to distinguish certain groups or classes of script heretofore unrecognized. The comprehensive study on this subject, however, must not be expected till conditions in Europe become more favorable. In the meantime, the best results can be obtained by focusing attention upon important single centers of writing, and one of the most important of these (Lyons) will have a special publication devoted to it during the coming year. It is pleasant to report that the instigation to such an undertaking has come from the authorities of the Library of Lyons, under whose auspices and at whose expense the work is to be done. Owing to the unsettled condition of Germany, the intended visits to the libraries of Fulda, Cassel, Cologne, and Berlin, which contain manuscripts of singular importance to the investigation in hand, have been postponed.

Traube's published list of uncial manuscripts has been considerably augmented, and a provisional list of half-uncial manuscripts, accompanied by references to published fascimiles, has been drawn up. It will be published, together with certain palæographical observations, in the *Mélanges Ehrle.*

During the winter the library of Orléans was visited and its ancient fragments carefully studied. In Paris the uncial and half-uncial manuscripts were re-examined and the occasion employed to inspect all the Visigothic manuscripts in the Bibliothèque Nationale, which possesses the largest collection of ancient Spanish manuscript outside of Spain, not excluding that at the British Museum, which had been previously examined. Among the Visigothic manuscripts examined, peculiar interest attaches to a fragment which shows evidence of having been copied from an original written by an Englishman. It contains a commentary of St. Matthew still unpublished, and through the courteous cooperation of the learned Benedictine Dom DeBruyne it has been possible to discover both the ancestor and the descendant of this fragment. The fragment is interesting both because it has never been published and because it suggests literary relations between Spain and some English center on the Continent, and also for the light it throws on the methods of scribes when confronted with foreign scripts. An article on the subject of this fragment, properly illustrated, will also appear in the *Revue Bénédictine.*

The preface to the Bobbio Missal will soon go to press; and the letter-press to accompany the 100 plates of the *Scriptura Beneventana* is being prepared for publication as soon as possible. Besides reviews in the English Historical Review and the Classical Review, a short note appeared in the latter periodical on the genuineness of the Berlin Plautus fragment.

It is gratifying to report that the authorities of the Bodleian Library have formally entered into an agreement whereby they become the temporary custodians of the collection of negatives, thus assuming a maximum amount of safety and accessibility to schools. The collection has been increased by accessions from the libraries of Rome, Florence, Bologna, Verona, Milan, Vercelli, Novara, Turin, Autun, Lyons, Cambrai, London, and Oxford. Through the kind cooperation of Professors Lehmann of Munich and Dobschütz of Halle, a number of negatives were made in the libraries of Fulda, Cassel, and Dresden. Grateful acknowledgment should also be made of a number of negatives presented by Professor E. K. Rand, of Harvard University.

Reference was made in last year's report to the catalogue of published facsimiles made for immediate purposes of the new collection of palæographical negatives; and the view was expressed that so valuable and convenient an aid to scholars should be printed as soon as possible. Confirmation is now afforded by the fact that the London Institute of Historical Research has asked for and received permission to make a copy of the catalogue.

PALÆONTOLOGY.

Case, E. C., University of Michigan, Ann Arbor, Michigan. *Study of the vertebrate fauna and palæogeography of North America in the Permian period, with especial reference to world relations.* (For previous reports see Year Books Nos. 2, 4, 8–21.)

The year was largely devoted to a study of the terrestrial deposits of Permian age in Europe, South Africa, and Australia. The exposures were traced and particular areas were studied intensively. The itinerary led through England and Scotland, from the Saar region across Germany to Prague and into the Permo-carboniferous basins of Czechoslovakia, into central France, the Maritime Alps, Italy, and Sicily. In South Africa several weeks were spent in the Karroo and as far north as the Zambesi River, identifying the various life zones and studying the fauna and the sediments. In Australia the glacial and interglacial beds of the Permian and Permo-carboniferous were examined at various localities. Final work was done in New Zealand.

Much time was spent in museums and libraries gathering literature and examining specimens. In every place visited information and guidance were given in the most courteous and helpful manner. Much of the value of the trip lay in the opportunity to discuss local problems with the men best acquainted with the areas. From the large amount of material gathered it is hoped that a report of value may be made upon the environment of vertebrate life in the late Paleozoic.

Chaney, Ralph W., Berkeley, California. *Research Associate in Palæobotany.* (For previous report see Year Book No. 21.)

Following the plan of work adopted several years ago, the fossil floors of the John Day Basin have served as the center of field and laboratory studies during the past year. The use of fossil plants from north-central Oregon as a starting point for the study of the Tertiary floras of the West is particularly appropriate in view of their occurrence there in three of the four major units of the Tertiary. The John Day Basin is centrally located with respect to several of the other Pacific Coast areas from which plant fossils are secured, giving this region a geographic advantage as a starting-point for correlation studies; and the plant fossils are abundant and sufficiently well preserved to give a fairly complete record of the plant life of the Tertiary.

Up to the present time, floras related to those of the John Day Basin have been found in the Coast Ranges near San Francisco Bay and in southwestern Oregon, on the west side of the Sierras from Tuolumne County into Plumas County, California, in the Cascades at the Gorge of the Columbia River and northward at Ellensburg, Washington, and in the Great Basin Province from northern Nevada, eastern Oregon, southwestern Idaho, and east-central Washington, and are roughly 700 miles from north to south and 300 miles from east to west. There are closely related floras in Eurasia from Switzerland to southern Manchuria, and northward in the polar regions. The study of the John Day plants may therefore be expected to throw light on the conditions existing in much of the northern hemisphere during the Tertiary.

Most of the work of the past year has been concerned with the intermediate of the three John Day floras, that from Bridge Creek, which is of Upper Eocene or Oligocene age. This flora, which is the most world-wide in distribution of the three, is characterized by the abundance of a sequoia similar to the living redwood (*Sequoia sempervirens*). Associated with the sequoia in the Bridge Creek flora are forms whose living relatives form part of the modern redwood forest of California. Of these, a species of alder and of oak closely related to the living red alder (*Alnus rubra*) and to the tanbark oak (*Quercus densiflora*) are the most abundant. The occurrence together of this group of fossil forms seems to indicate the existence in the early Tertiary of conditions closely similar to those producing the modern redwood forest in the Coast Ranges of California. It seems safe to predict that a continued study of this living forest will furnish many suggestions as to the floristic nature and physical requirements of the related Tertiary floras.

Besides the conspicuous redwood element in the Bridge Creek flora, there is a group of about half a dozen species representing genera no longer found on the Pacific Coast, but all of which are common to-day in the moist forests of the eastern United States and Europe. Their absence now in the West appears to be the result of climatic restrictions imposed during the Pleistocene and of mountain barriers which serve to limit migration westward. In all of the work involving taxonomic and ecologic comparisons between fossil and living forms, the suggestions of Dr. Frederic E. Clements and Dr. Harvey M. Hall, of the Carnegie Institution of Washington, and of Dr. Willis L. Jepson, of the University of California, have been of great service.

A definite start has been made on the study of fossil wood. The United States Geological Survey, through the kindness of Dr. David White, has made a considerable number of thin sections from wood secured at localities furnishing Tertiary leaves. These have been studied, in cooperation with Dr. Clements, and appear to show characters which will be of diagnostic value in checking the generic references made from a study of the leaves alone.

A number of new fossil localities has been discovered through the assistance of the staff and students of the Department of Geology and the Museum of Palæontology of the University of California and of the staff and students at Stanford University. One of the most interesting of these has furnished what appears to be a Pliocene flora from the Coast Ranges near Santa Rosa, California. Although of small size, this flora is of particular interest since it tends to fill the gap at the upper end of the Tertiary, from which few plant fossils have been found.

Hay, Oliver P., U. S. National Museum, Washington, District of Columbia.
Report on work done on the Pleistocene epoch and its vertebrate fossils.
(For previous reports see Year Books Nos. 11–21.)

A large part of the time during some months since September 1922 was occupied in proof-reading the volume on the pleistocene and its vertebrates of the region east of Mississippi River. This volume was issued as publication No. 322 in February 1923. All of my available time during that period and since has been employed in the final preparation for the press of the volume on the same subject for the middle region of North America. This is now ready for publication.

Description of the Pleistocene and its vertebrate fauna for the region west of the Rocky Mountains is being prepared and is well advanced.

Merriam, John C., and associates. *Continuation of palæontological researches.* (For previous reports see Year Book Nos. 20, 21.)

The palæontological investigations of the past year have been conducted with special emphasis upon the following problems:

1. Palæontological succession in the extensive series of formations in the John Day region of eastern Oregon considered with special reference to relation of the history of life to history of crustal movement and igneous activity in this region.
2. Relation between the study of the history of plants in the Pacific Coast region, conducted by Ralph W. Chaney, and investigation of general palæontological succession of higher animals, by Dr. Merriam and Dr. Stock.
3. Advance in the series of extensive monographs of mammal and bird faunas from asphalt beds of Los Angeles.
4. Further advance in studies of mammal and bird faunas from asphalt deposits near McKittrick, California.
5. Study of the history of whales and seals, by Remington Kellogg.

Investigation of the history of animal and plant life of the great series of late geological formations found in the John Day region of eastern Oregon was begun in 1899 through an expedition from the University of California under the direction of Dr. Merriam. It was continued in an expedition of 1900 and again in 1901 by studies made by F. H. Knowlton, of the U. S. Geological Survey, and J. C. Merriam. In subsequent years minor expeditions conducted further investigations into the life of this region and of the geological formations in which the fossils occur.

As this region represents one of the best-known sections for studies giving relation between the factors involved in this investigation, the succession of strata is being mapped in detail in order to work out the history of life in relation to the history of crustal movements. To assist in this work the United States Geological Survey has begun the construction of a topographic map. When the United States became involved in the World War the topographic work was discontinued, but through the kindness of the Geological Survey it was taken up again in the summer of 1923, thus offering the possibility for realization of the extensive plan which had been initiated.

Studies of the John Day region as now planned involve:

First, the complete mapping of all geological formations in this region, to be carried out under direction of J. P. Buwalda, of the University of California, with the assistance of specialists in several fields of geology and palæontology.

Second, intensive study of history of the great extrusions of molten material represented in the enormous lava fields of this region, this investigation to be carried on under the direction of Fred E. Wright.

Third, mapping of the zones or series of strata characterized by different types of plant or animal life, this work to be conducted by Dr. Buwalda, Chester Stock, and R. W. Chaney, with the assistance of other investigators.

Fourth, detailed study of the succession of plant remains.

Ralph W. Chaney has continued his review of the principal occurrences of plant remains in the Pacific Coast and Great Basin regions of the United States, and has made much progress in his intensive studies of certain sections containing exceptional material or an unusually important sequence of plant remains. Special attention has been given to the succession of plant remains in the John Day basin with its wide variety and extended geological range of floras. The exact position of the floras in the stratigraphic sequence, character of the formations in which fossils are embedded, nature of climatic conditions under which plants lived, examination of the wide variety of species represented, and the significance of the collection as a whole in terms of climate and environmental conditions have all required special attention.

Dr. Chaney's recent study on the Bridge Creek flora of the John Day region, heretofore assumed to be of Miocene age, has given us for the first time a careful statistical statement of the species present. Of 20,000 specimens obtained in the most recent collections, 45 per cent are alder, 14 per cent sequoia, 10 per cent oak, and 10 per cent laurel (*Umbellularia*). There were found to be slight differences in the percentages of the common species from the several levels from which specimens were secured, but in general the representation of plant life is essentially the same through this section. The flora as a whole has a strikingly close resemblance to that of a redwood forest region of the present day on the West Coast.

Studies of the extraordinary asphalt faunas of the Pleistocene at Rancho La Brea in Los Angeles and at McKittrick on the western border of the great valley of California have advanced rapidly during the year and several papers have already been approved for publication. These include the monograph on the sloths by Chester Stock, a study of the fossil bears of the genus *Arctotherium* from western North America by J. C. Merriam and Chester Stock, and a number of shorter papers. Two other monographs will be submitted for publication in the early part of the coming year.

The monographic studies of the fauna at Rancho La Brea covering cats, camels, and horses will be published as early as it is possible to secure complete illustrative material.

Excavations in the asphalt deposit near McKittrick have been continued and much additional material secured. The recent collections, representing both mammals and birds, are being prepared for study under the supervision of E. L. Furlong with assistance furnished by the Museum of Palæontology of the University of California.

Dr. Stock in cooperation with Mr. Furlong has also been engaged in studies of Pleistocene and Pliocene faunas from several localities in California, Oregon, and Nevada, these investigations being closely related to special studies at Rancho La Brea and McKittrick.

In an investigation of the geological history of the birds of America, L. H. Miller, of the Southern Branch of the University of California, has continued his important work conducted in cooperation with and through the courtesy of the Los Angeles Museum. His monograph on fossil birds of Rancho La Brea has been accepted for publication along with a paper of extraordinary interest on a bird fauna secured in the Miocene diatomaceous deposits of Lompoc, California.

As an end result of Dr. Miller's studies, the Los Angeles Museum has this year placed on exhibition a nearly complete assembled skeleton of the great carnivorous flying bird, *Teratornis*, found only in the asphalt beds of Los Angeles and in the similar beds of slightly different age at McKittrick, California. The assembling and mounting during the year 1923 of this skeleton by the Los Angeles Museum represent an important advance in our knowledge of extinct life of America.

Remington Kellogg has continued his extraordinarily interesting work on the evolution of whales, having included in his studies the history of whales and seals on both the Atlantic and Pacific coasts of the United States.

Mr. Kellogg has brought to completion, and in some instances to publication, six important papers including descriptions of new and interesting material representing the whale group from South Carolina and the coast of Maryland and new data regarding the extremities or flippers of an extinct member of the seal group from southern California. To the results contributed through these papers there should be added three important studies of new whale material from the Miocene formations of California and an important discussion of the comparative anatomy of a portion of the ear region of whales, both recent and extinct.

Wieland, G. R., Yale University, New Haven, Connecticut. *Associate in palæontology.* (For previous reports see Year Books Nos. 2–4, 6–9, 11–21.)

A quantitative study based on the fossil plant record has indicated a strong resistance to the proximate environmental factors, quite throughout geologic time. Numerically, ancient plants were finite. The course of change was simple, the lines of descent parallel, and time long. These results are ready for publication elsewhere, and a briefer paper on the Liassio-Oölitic boundary in the Mixteca Alta region of Mexico has been prepared.

During the past winter Dr. Dahlgren, of the Field Columbian Museum, Chicago, examined, in consultation with reference to detailed structure, the cycadeoid types of flowers. His glass models of these (brought nearly to completion) are of beauty, interest, and scientific value. This renewed attention has served to emphasize the fact that the cycadeoid perianth, with the coalescent stamens and the ovulate cone, is comparable to the most instead of the least specialized angiospermous flowers. The cycadeoid floral structures exactly parallel those of existent "perfect flowers." Organically speaking, whether viewed as the result of reduction or as examples of gigantism, the flower of *Cycadeoidea*, especially, is of advanced type. Its parts are those of the flower of Linnæus, of Goethe, and of Payer.

The U. S. National Museum has resumed cooperation in the investigation of the petrified cycadeoids by cutting a group of interesting types. These include a splendid new stem from half a mile east of Comanche, Texas. This has been donated by its finder, Mr. Bart Johnson, of Comanche. Cutting of this stem, polishing, and illustration are near completion. There was also secured during the year an additional *Cycadeoida dartoni* stem from near the locality of the original type. The new specimen is particularly interesting because it is without fruits, in striking contrast to the great seed-cone series borne by the type.

No field work has been done this year, and no laboratory work at Yale, aside from some photography. The laboratory unit at the Oyster River (cf. Year Book 20, p. 457), West Haven, Connecticut, has been in use. The Harvey Lewis Company, of New Haven, has again kindly made certain thin sections of the cycadeoids.

The materials for volume III of the American Fossil Cycads appear to be at hand, and it is trusted that this continuation of published work is now so well along in preparation that it may not again need mention in a Year Book report. Most of the plates are assembled or the material for them is in view. The chapters or their outlines have taken form. The subjects for the pen drawings of the text are the more difficult incomplete part of the work.

During the year two events have greatly heartened paleobotanists in general. One is the publication, by R. E. Torrey, of descriptions of a number of lignitic gymnosperm stems sectioned by methods brought into use by Jeffrey. Although there may not be agreement with all the conclusions as to lines of descent, one may for the first time more fairly speculate on the distribution and antiquity of the North American pines and araucarians. Difficult to work with, but in reality the stage preceding silicification and retaining the critical structures far more perfectly on the average, lignitized material is far more abundant than is commonly recognized. The hope is again expressed that well-lignitized cycadeoids may not fail of discovery. From such, well sectioned, the last word could be said about structure, and particularly affinity to earlier angiosperms as contrasted with pines, for so far no direct knowledge of the stem structure of the more generalized cycadeoids has been brought to light.

The second event, perhaps the most notable in American palæobotany since the appearance of Hollick and Jeffrey's studies of the lignitized conifers of Long Island, is the announcement from the University of Chicago of the long-awaited discovery of "coal balls" in the Pennsylvanian of Illinois and Kentucky. As the first result of study, small stems with a somewhat primitive but nevertheless determinate monocotyledonous structure have been described by J. H. Hoskins. This is a momentous extension of the angiosperm record, fully justifying ideas of plant antiquity and parallelism in descent outlined in volume II of the American Fossil Cycads (cf. p. 206 *et seq.*).

PHYSICS.

Barus, Carl, Brown University, Providence, Rhode Island. *Continuation of investigations in interferometry.* (For previous reports see Year Books Nos. 4, 5, 7–21.)

During the course of the year Professor Barus continued his work with the interferometer U-gauge. A new installation was made, in which the mercury surfaces were 10 cm. in diameter, the object being to keep them more rigorously in parallel throughout all displacements. The charge of mercury must be introduced in vacuo. In this way the range of available pressures was increased.

The gage was first used in an endeavor to measure small pressure increments or decrements accruing slowly in the lapse of time and due to gas evolution or absorption, vapor-pressure phenomena, etc. Though pursued at some length, the results remained untrustworthy, because of the concomitant temperature effects; for the closed region is also an exceedingly sensitive air thermometer. These difficulties fall away, however, when the region is closed by a liquid film; for the pressure is then determined solely by surface tension of the film. Accordingly, a variety of experiments was made on the pressures within bubbles, from which the surface tension could be computed up to the point at which the film ceases to be contractile. In glue bubbles, for instance, the surface tension rose from about 30 to over 80 dynes/cm. in the first 5 minutes of exposure, after which, with incipient solidification, the increase of pressure was suddenly arrested. The excess of air within the bubble completely escaped through the solidifying iridescent film during the ensuing 150 minutes or more. Similar work was done with solutions of sugar in water, or resin in chloroform, or pitch in turpentine, and with collodion. In case of a colloidal solution, by successively diluting the soap or glue content the surface tension T of pure water was finally very closely approachable, $T > 60$ being reached before the bubbles were too evanescent for use.

The endeavor to apply interferometer methods to the capillary electrometer was not successful; but with the apparatus at hand, a study of the march of the phenomena on gradual dilution of the electrolyte to very pure water was completed and certain marked advantages of a change of form of the apparatus were indicated. Interferometer methods for the transpiration of gases also fell short of interpretable results, chiefly because pin-holes fine enough were not to be obtained. On the other hand, interferometer measurements of the viscosity of gases passed through capillary tubes led to favorable results at once.

The chief application of the new interferometer U-tube throughout the year embraced a continuation of the acoustic researches begun in the preceding report. The acoustic pressures generated by paired pin-hole probes serve admirably for ascertaining the mode of vibration encountered in closed regions of any form. The results obtained with tubes closed at both ends were particularly interesting, and the work was therefore developed systematically, the tubes of all lengths ranging in diameter from 0.4 to 2 cm. It is somewhat startling to find 4-inch quill tubes responding to the notes of the 4-foot octave. In tests of this extreme severity, the results do not follow the theoretical equations, and an exhibit of the phenomena in terms of dimensions, viscosity, and frequency was therefore attempted. A few supplementary experiments were made with horns and branched tubes.

The investigations of the behavior of the gravitation needle in a partial vacuum were pursued through the summer of 1922 and a complete set of night observations was recorded. In addition to the static deflections of the needle, periods and logarithmic decrements were also tabulated, all under a variety of experimental conditions. All are fundamentally subject to discrepancies, owing to the uniform presence of radiant forces. The endeavor to disentangle these complications was but partially successful and led to no trustworthy results. The apparatus has since been taken apart and the period in question determined indirectly. Using the night observations of 1922, which as a whole were remarkably uniform, the final outcome was nevertheless disappointing. It does not appear that, under ordinary reasonable laboratory conditions in the summer and a quartz fiber apparatus, the gravitation constant can be obtained with a degree of assurance exceeding 1 per cent of uncertainty.

Hayford, John F., Northwestern University, Evanston, Illinois. *Investigation of the laws of evaporation and stream-flow.* (For previous reports see Year Books Nos. 12–16, 19–21.)

One year ago this investigation was concentrated on the study of evaporation from the Great Lakes, using observations on Lake Superior and on Lake Michigan-Huron. For Lake Superior one least-square solution (involving a single month of observations on Lake Superior) had been completed and four such solutions for Lake Michigan-Huron, each involving either one or six months of observations of the elevation of the lake-surface. The evaporation investigation rested directly upon the investigation of effects of winds and of barometric pressures on the Great Lakes which had been completed during the preceding year.

During the year ending September 5, 1923, five more least-square solutions for determining the evaporation from Lake Superior were completed. The last four of these five were each based upon 6 months of observations of the elevation of the water-surface. At the close of the year a solution based upon 28 months of observations was in progress.

During the year four more least-square solutions for determining the evaporation from Lake Michigan-Huron were completed. Three of these were based upon 6 months of observations of the elevation of the water-surface of Lake Michigan-Huron, and the last one was based upon 28 months of observations, the warmer months of 5 years.

The investigation has now progressed sufficiently to make it certain that when the evidence from 28 months of observations on each of the two lakes, Superior and Michigan-Huron, has been fully analyzed by the methods now in use, the constants in the formula expressing the evaporation for each day from these lakes in terms of the temperature, vapor pressure, and wind velocity, as observed by the Weather Bureau, will have been determined with a fair degree of accuracy. It will then be possible to compute, with reasonable confidence, the evaporation on any day from any such water-surface anywhere in the world in terms of the meteorological elements observed in the vicinity of that lake, reservoir, river, gulf, or sea. It is reasonably certain that the analysis of the evidence from 28 months of observations on each of these two lakes will be completed during the year 1924.

The primary object of the determination of evaporation by this investigation was to furnish a safe basis for certain investigations of stream-flow. During the past year, when fairly good values for the evaporation constants had become available, the direct investigation of stream-flow was commenced and is now being carried forward at the same time that the evaporation investigation is being completed. As was expected, this has already thrown valuable sidelights on the evaporation investigation and has thus promptly justified the overlapping of the two related investigations of evaporation and of stream-flow.

On September 5, 1923, four least-square solutions, each dealing with the observed discharge for one or two months on one or the other of two small streams in Colorado, have been completed. These solutions indicate that the theory on which this investigation is based is sound and that the method of investigation is capable of furnishing rapid progress in determining the laws connecting stream-flow on the one hand with the observed meteorological elements in the drainage area of the stream on the other hand.

Millikan, R. A., Norman Bridge Laboratory of Physics, Pasadena, California.
Research associate in physics.

Under the 1922–23 grant of $15,000 by the Carnegie Corporation of New York for work on atomic structure to be carried on in the Norman Bridge Laboratory of Physics, the 35 subjoined distinct researches have been carried on by 31 different men, all of whom have received assistance in greater or less amount from this fund. The results obtained so far have been reported in 17 different papers read before the American Physical Society. A few of these researches which have yielded results of somewhat more than the usual interest are selected for brief description.

1. The magnetic investigations conducted by S. R. Williams, in addition to bringing to light some interesting relations between the changes in the dimensions of iron and steel bars and their magnetization, have incidentally yielded a new magnetometer which may revolutionize the making of magnetic surveys. It is a simple, rugged, and easily portable instrument, capable of giving a determination, accurate to 1 part in 1,000, of the horizontal or vertical components of the earth's magnetic field in a few minutes of time and also of exploring quickly and accurately the magnetic fields of solenoids, electromagnets, etc.

2. The work of Messrs. Millikan and Eyring in pulling electrons from cold metallic surfaces by static fields has shown:

(*a*) These currents set in from untreated tungsten at a field-strength of about 200,000 volts per centimeter and rise a billionfold, nearly reversibly, as the field increases to 1,000,000 volts per centimeter.

(*b*) This phenomenon of the pulling out of electrons is entirely independent of temperature.

(*c*) It is a phenomenon which is dependent upon the electron affinity of the very surface molecules, an electro-positive molecule on the surface acting apparently as a hole through which the reservoir of electrons inside may be tapped so as to produce a well-nigh unlimited flow.

These results are of both scientific and industrial interest.

3. The experiments of Otis, Bowen, and Millikan have established the existence of a very penetrating radiation in the upper regions of the

atmosphere, but they have also shown that the intensity of this radiation is, but about one-fourth as great as previously supposed. The origin of these as yet mysterious rays is being diligently sought by experiments now in progress on Pike's Peak and in sounding-balloon flights which have already been carried to nearly twice the altitudes reached by previous observers in experiments of this kind.

4. The photo-electric experiments of Nielson and Kazda have cleared up former uncertainties as to the effects of surface films on the ejection of electrons by light and have established with great definiteness and precision a critical frequency at which any perfectly clean surface begins to be photosensitive. These critical frequencies have been accurately determined for aluminum, nickel, and mercury. The experiments bring out sharply the distinction between the electrical constants of a surface and those of the molecules or atoms composing the surface and indicate the only method by which the work necessary to remove an electron from a cold surface can be accurately measured.

5. Dr. Epstein has given the solution (now checked experimentally) of the problem of the reflection of molecules, which had baffled physicists for fifty years. These results are of much theoretical interest and they are also of some practical value for the problem of the rate of settling of dust in the upper atmosphere.

6. Messrs. Millikan and Bowen, in their work in the extreme ultra-violet spectrum, have brought to light, and found the origins of, about 1,000 new ultra-violet lines. They have shown that the exact positions of some of the most important of these lines are predicted by the "Bohr" theory, and they have found evidence that the strongest lines of the extreme ultra-violet spectra of the elements from lithium to carbon are produced by atoms which have been stripped of all of their valency electrons. This last result is of much interest in its relation to the problem of atomic structure.

Researches under way in the Norman Bridge Laboratory of Physics.

1. Atomic radiations in the extreme ultra-violet. R. A. Millikan and I. S. Bowen.
2. Measurement of the penetrating radiations of the upper air by sounding balloons. R. A. Millikan and I. S. Bowen.
3. Attempt at reconciliation of the corpuscular and the wave theories of radiation. Harry Bateman.
4. The mass of the electron in metals. R. C. Tolman and L. M. Mott-Smith.
5. The new and very sensitive method of measuring the magnetic properties of gases and vapors. L. M. Mott-Smith and R. C. Tolman.
6. Photo-effects and ionizing potentials at liquid air temperatures. R. C. Burt.
7. The energy necessary to detach electrons from a clean mercury surface. C. B. Kazda.
8. The change with the angle of emission of the energy of electrons ejected by light. E. C. Watson.
9. Low voltage arcs and cumulative ionization. James B. Friauf.
10. The precise evaluation of the ionizing potentials of neon and allied gases and vapors. H. K. Dunn.
11. The penetration of atoms by low-speed electrons. R. C. Brode.
12. The electrostatic field-strengths necessary to pull electrons from different metallic surfaces. R. A. Millikan and C. F. Eyring.
13. Number of electrons detached from different atoms by shooting single alpha rays through them. R. A. Millikan and A. L. Greenlees.
14. Energy of impact of positive particles necessary to detach electrons from metallic surfaces. A. L. Klein.
15. Analysis of the atoms of very refractory substances for isotopes. A. H. Warner.
16. Analysis of soft X-rays by magnetic-beta-ray method. J. A. Becker.

17. The stimulation of special lines by light frequencies other than those emitted. Stanislaw Loria.
18. A search for an effect of temperature upon photo-electric emission. J. Rudd Nielson.
19. Photo-electric analysis of radiations between the X-ray region and the optical region. E. H. Kurth.
20. Magnetostriction as a function of crystal-orientation. S. R. Williams.
21. Magnetic properties of sputtered cathode films. G. H. Cameron.
22. Development of a very high-voltage constant potential generator. J. W. M. DuMond.
23. Direct observation of the paths of B-rays in passing through atoms. D. H. Loughridge.
24. Penetrating radiations on mountain peaks and in high airplane flights. Russel M. Otis.
25. Measurement of the radioactivity of ordinary materials. I. S. Bowen.
26. A new magnetometer. S. R. Williams.
27. A comparison of Barkhausen effects with magneto-stictive effects. S. R. Williams and H. K. Dunn.
28. The laws of reflection of molecules. Paul S. Epstein.
29. Quantum relations in magnetism. Paul S. Epstein.
30. The combined Zeeman and Stark effects. Sinclair Smith.
31. New series relationships in spectra. J. A. Carroll.
32. Seismological and earth-tide measurements in southern California. W. T. Whitney.
33. Mobilities of ions in flames as a function of inserted salts. W. M. Zaikowsky.
34. A quantum theory of dispersion. C. G. Darwin.
35. Interference phenomena in white light when a thick glass plate is compensated by air. W. N. Birchby.

Nichols, E. L., Cornell University, Ithaca, New York. *Report on studies in luminescence.* (For previous reports see Year Books Nos. 4–21.)

Among the topics under investigation during 1923 the constitution of luminescence spectra should probably be given first place. Aside from the line-like spectra exhibited by certain fluorites holding traces of the rare earths in solid solution, it had been known for some time luminescence spectra in general might be divided into two classes:

(*a*) The broad-banded spectra of such phosphorescent substances as willemite, sidot blende, and the Lenard and Klatt sulphides.

(*b*) *The narrow-banded spectra* of the uranyl salts and of certain organic compounds.

In 1917 [1] a detailed spectro-photometric study of the fluorescence spectra of three of the Lenard and Klatt sulphides, made by Professor H. L. Howes, at the writer's suggestion, brought out the unsuspected fact that the very broad bands which are characteristic of these spectra are made up of two or more groups of equidistant components.

In 1918 [2] investigation of the phosphorescence spectrum of a calcite from Franklin Furnace revealed a similar structure, and in the same year Howes showed that the fluorescence bands of iodine vapor as measured by McLennan [3] can also be arranged in several series having intervals of constant frequency.

The extended spectro-photometric investigation of kathodo-luminescence, done by Mr. T. Tanaka in our laboratory (see Year Book No. 21, p. 389), is now completed and four papers containing the results are ready for publication. The principal points may be briefly summarized as follows:

(1) The kathodo-luminescence spectra of 129 solid solutions with 42 metals as active agents were studied. Of these, 27 were Lenard and Klatt sulphides;

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[1] Nichols, Amer. Philos. Soc., LVI, p. 261 (1917).
[2] Nichols, Howes, and Wilber, Phys. Rev. (2), vol. XII, 364 (1918).
[3] Howes, Science, n. s., vol. XLVI, 96 (1918).

the remainder were, for the most part, specially prepared for this research by Mr. Tanaka.

(2) Each dissolved metal was found to have its characteristic luminescence spectrum, composed of one or more series (usually two or four series) of overlapping bands.

(3) These bands, expressed in frequency units, are equally spaced.

(4) The location and frequency interval of the bands are the same for a given metal and are independent of the solvent.

(5) The position of the crest of the envelope of the entire group of bands, i. e., the position of maximum brightness in the spectrum, shifts toward the violet with increasing molecular weight of the solvent.

(6) The frequency interval is definitely and inversely related to the atomic weight of the activating metal, and Mr. Tanaka has identified, by means of this relation, the active element in numerous calcites, fluorites, and other luminescent solids.

Constant Frequency Intervals in Flame-spectra and in Incandescent Solids.

The search for constant frequency intervals in flame-spectra (made by Miss M. A. Ewer) has been completed. All the flame-spectra recorded by Eder and Valenta[1] have been studied, and it is found that the lines and bands recorded by them as occurring in the spectra of some 23 elements are capable of arrangement in groups or series having a constant interval, and that the intervals thus found, as in the case of the kathodo-spectra measured by Tanaka, *are definitely related to the atomic number of the element.* The curves of these two investigators, which are very similar, are not identical in their present form, and their precise relation to each other is being investigated.

In view of these facts it seemed desirable to study the continuous spectra of flames in which such metals as calcium, magnesium, aluminum, etc., were in process of combustion; also to investigate their oxides and other oxides which show unusual types of incandescence.

Photographs of these spectra[2] were made by Dr. L. J. Boardman at my request and were measured as to density in great detail upon his microcomparator with photo-electric cell and slit. Explored thus step by step, several hundreds of measurements a small fraction of a millimeter apart being taken, these continuous spectra *show a definite structure* hitherto unsuspected because invisible. Like the kathodo-spectra of luminescent solids, they are made up of several series of overlapping and submerged components, equidistant as to frequency. The intervals correspond to those found by Miss Ewer for the flame-spectra of the respective metals, and the location of the crests is such as to fill out the missing places between the lines of the flame-spectrum.

Results obtained with certain photographs of incandescent tungsten (to be mentioned at present as preliminary and with due reservations) indicate a probability that the above structure is common to all incandescent solids.

Photo-luminescence of Flames.

The photo-luminescence of flames (see Year Book No. 21, p. 387) has been further investigated during the current year, and it has been found that in addition to the enhancement of the bands previously measured[3] certain definite modifications of the flame-spectrum are observable. In general the bands of flames containing Ca, Sr, and Ba are rendered narrower and less hazy when the flame is exposed to the exciting light; black grounds tend to become blacker; narrow components of some of the broader bands, which may be scarcely discernible when unexcited, come out more clearly; the dark lines between the crests of double bands become deeper and, in a word, there is a tendency towards better resolution of the spectrum.

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[1] Eder and Valenta, Atlas Typischer Spectra (1911).

[2] Boardman, Phys. Rev. (2), vol. xx, p. 552 (1922).

[3] Nichols and Howes, Phys. Rev., xxii, p. 425 (1923).

A very striking and instructive example of photo-excitation, unique as yet in our experience, is the green line of thallium. When excited by an amalgam mercury arc in quartz this line increased in brightness more than 50 per cent (in one instance many times). This unusual sensitiveness was found to be due to the presence of the thallium lines in the amalgam arc. To these wave-lengths in particular the thallium in the flame is opaque and capable of absorbing the energy necessary to excite luminescence.

MISCELLANEOUS.

Professor Frances G. Wick has completed her studies of the luminescence of certain fluorites (Year Book 21). She finds that by heating these crystals to fusion the rather broad-banded spectrum is converted into a spectrum of *exceedingly* fine lines, the narrowest perhaps as yet known in fluorescence spectra. There are the lines of Samarium, Europium, Dysprosium, and other rare earths, to the presence of traces of which the luminescence of these fluorites is due. Heating also brightens and prolongs the phosphorescence of the crystals.

The work on the effects of great pressure upon absorption and fluorescence, which Miss Wick did in collaboration with Professor Bridgman, is being published by the American Academy of Arts and Sciences.

Mr. Paul Bayley has just completed an investigation of the fugitive coloration of the salts of Li, Na, K, Cs, and Rb by the action of X-rays and of the phosphorescence of these salts under X-ray excitation.

Some recent experiments by Miss Dorothy Waugh afford valuable data for the development of the theory of the "*dark current*" in photo-active electrolytic cells.

Plans are being developed to attack the important general question as to whether all cases of luminescence depend upon the presence of an admixture of an activating metal or element. Preliminary experiments are already under way by Mr. Wilber to investigate the most important exception, that of the uranyl salts. Tests of the platino cyanides are also being devised.

SEISMOLOGY.

(For previous reports see Year Books Nos. 20, 21.)

REPORT OF THE ADVISORY COMMITTEE.

In reviewing the advances made during 1923 toward the study of California earth-movements, with which the Advisory Committee in Seismology has been charged, it is profitable to recall the fact that the procedure recommended by the committee and adopted by the President and Trustees of the Institution differs from the one usually followed in the pursuit of seismologic research. In the judgment of the committee, a single observing station, however carefully located, completely equipped, or competently served, would by itself yield little more than a routine record of local or distant disturbances. It is rather through a comprehensive study of surface features, of geologic structure, of the physical, particularly the elastic, properties of the rocks, of the distribution, direction, and magnitude of the tremors and displacements which occur and their relation to permanent zones of structural weakness, that an understanding of these movements and their proximate causes is to be sought. Of all these things the conventional seismograph, even of stations of the first class, can tell us only a part; of local earthquakes of short period, such as the California earth-movements for the most part have been shown to be, it can tell us extremely little.

It is for these reasons that your committee has departed from the practice which has been developed in other countries where earth-movements are studied, and sought the cooperation of those agencies which, more competently than any others, are able to furnish precise information about the surface and the structure of the portion of the earth's crust which it is proposed to study. These are the Seismological Society of America, the U. S. Coast and Geodetic Survey, the California Institute of Technology, the Hydrographic Office of the U. S. Navy, the U. S. Geological Survey, the University of California, Stanford University, the Observatories at Mount Hamilton, Ukiah, and Mount Wilson, the U. S. Bureau of Standards, and the Geophysical Laboratory of the Carnegie Institution of Washington.

The plain purpose of such collaboration is to establish, with the highest precision attainable, the present position of all useful surface landmarks, both above and beneath the sea; to measure the aggregate displacements of the past on active faults; to discriminate strained portions of the earth's crust from unstrained and to seek out the forces which operate to produce strains; to discover the composition, the physical structure, the geologic age, the density, and the elastic properties of the rocks which compose this composite crust, and in particular the zones of structural weakness in it; to develop instruments competent to analyze and measure elastic tremors, differences in pressure, and density; and to study any other factors which may affect the stability of the structure under observation. In this manner it is hoped to attain to a competent knowledge of the character, the proximate causes, and trend of development (in both time and space) of the earth-movements of the region selected for the initial studies (California).

With this brief statement of purpose in mind, the details of the year's progress will be readily understood.

1. Fault-zone Geology.

The local subcommittee on California fault-zone geology, under the chairmanship of Professor Bailey Willis, of Stanford University, including in its membership Professor A. C. Lawson, of Berkeley, Dr. Ralph Arnold, of Los Angeles, Mr. Fred P. Vickery, of the Southern Branch of the University of California, and Mr. L. S. Noble, of the U. S. Geological Survey, has been very active during the past year and has concluded in a most satisfactory manner the first chapter of its task. Although pressed for time and without adequate personnel for so comprehensive a survey, this committee has managed to bring together all of the available information pertaining to the location of known fault lines in California, and the Seismological Society has published it as a supplement to its March Journal (1923).

It is a natural consequence of somewhat hasty preparation that some of these fault zones have been much more carefully studied than others. It also happened that the group of geologists working in the northern part of the State and the group working in the southern part did not adopt exactly the same system of definitions, but these are minor limitations when compared with the amount of information which has been brought together. The picture here displayed of the zones of structural weakness along the west coast is most illuminating and serves to emphasize very clearly that here is a region where readjustments of considerable scope are in progress.

The Seismological Society of America has done a very great service to California and to all students of seismologic problems in bringing this information together, and when further studies have prepared the way for a second and more complete edition of this map a new era in the study of these hitherto somewhat mysterious phenomena, which, in this region, have such a direct bearing upon human safety, will have been inaugurated. It is just here that earthquake prediction attains its first significance—prediction not in time but in space, which is much more important; the regions where earthquakes are likely to occur are here plainly indicated.

Upon this same map there has been incorporated the new group of undersea contours, prepared from five thousand new soundings made by the Hydrographic Office of the Navy Department and covering an area of about 34,000 square miles, which displays the conformation of the ocean floor adjacent to the fault zones of the California coast region. This is the most elaborate study of submarine contours ever attempted. It has not only served to delineate effectively the continental shelf, but also to indicate many major displacements, the relation of which to the land faults is of great importance. From the heights of the Sierra to the foot of the continental shelf is a difference of elevation of more than 25,000 feet (5 miles) within a distance of no more than 232 miles. That such extreme differences of loading within a small area should produce strains which occasionally demand release is in no way surprising. Indeed, it serves to emphasize in an unmistakable manner the need for a systematic study of these strains and their readjustment. It is hoped that the Navy Department will find opportunity to continue these soundings along the entire west coast of the United States (including Panama), and as the power of its ingenious sounding device is increased to extend them to greater depths. The committee is under great obligation to the Navy Department and to Captain F. B. Bassett, Chief Hydrographer, for their keen interest and cordial cooperation in the pursuit of this problem.

2. SURFACE DISPLACEMENTS.

The plan of spreading an accurate network of primary triangulation over those regions of California which are particularly subject to earth-movements has made splendid progress during the past year. The U. S. Coast and Geodetic Survey obtained an appropriation of $15,000 for beginning this work in July 1922, and during that year measured a double system of triangles from the Sierras (Mount Lola and Round Top), across the Great Valley and the Coast Range, to the Pacific Coast. During the past year, under a continuance of the appropriation, the triangulation has been continued southward along the coast and is expected to reach nearly or quite to the Mexican boundary before the close of the present season.

The Coast and Geodetic Survey has been much interested in this work and has put forth an extraordinary effort to carry it out with the highest precision attainable. Although the results of these surveys have not yet been reduced and formulated, it is possible to say that a great many displacements have occurred since the last survey, including one which is of particular importance and affects all of the measurements which were made in connection with the great San Francisco earthquake of 1906. It will be recalled that in the two field seasons following the earthquake (1906–1907) a careful survey of the disturbed region was made under the direction of Mr. Hayford, which subsequently formed the basis of a report by the Coast and Geodetic Survey (Hayford) and one by the Carnegie Institution of Washington (A. C. Lawson). Upon these reports our present information regarding that great disturbance mainly depends. Hayford's triangulation of 1907 was referred to the Mocho-Diablo base-line, but no survey connecting this base-line with the crest of the Sierras was made at that time. Now that the present survey has revealed the fact that this base-line has shifted its position since the last survey some 30 years ago, we are left at a loss to know what its position may have been at the time when the earthquake survey was referred to it in 1907.

This situation may serve to emphasize, if emphasis be needed, the vital importance of these surveys at appropriate intervals as a preliminary to any serious discussion of earth-movements in California.

Similarly, the work of the past summer, although still incomplete and in no sense ready for discussion, has, nevertheless, clearly shown many such displacements, some of 20 feet or more, along the coast between San Francisco and the Mexican boundary, of which we had no intimation from any other source. The further study of these data should also tell us plainly whether we are dealing here with a number of independent displacements revealing zones of structural weakness and local movement or whether we have to recognize a general crustal creep of this region. The value of this information, whether considered from the economic or the scientific viewpoint, is immediately obvious.

3. SOUTHERN CALIFORNIA.

In the report of last year attention was called to the fact that our geological knowledge of the southern part of the State was less complete than of the northern part, except possibly in a few regions which have been especially examined for oil deposits. Accordingly the major portion of the time of Mr. H. O. Wood, Research Associate in Seismology, and of Messrs. L. S. Noble and W. S. W. Kew, of the U. S. Geological Survey, has been devoted to a detailed geological study of this region. This work has been continued throughout the past year by Noble and Kew; and so far as it has revealed active faults, they have been made a matter of record and incorporated in the fault map above mentioned.

Particular attention has been given, this year as last, to the San Andreas rift zone, and a considerable amount of new information has been gathered regarding its exact location and the recent activity there. It has been the plan from the beginning to place in this region the first installation of seismologic instruments for the detection of local movements as soon as the instruments should be ready. It is therefore of prime importance that our geologic knowledge of the region should be as complete as possible in order that the tremors which it is proposed to trace there may be intelligently observed. During the present season the detailed mapping will probably be carried over the San Gorgonio Pass through one of the most interesting regions along the entire path of the San Andreas fault. To the U. S. Geological Survey, under whose auspices Messrs. Noble and Kew have been able to give so much time to the problem during the past two years, the committee is indebted for contributing one of the most interesting features of the investigation.

During the last half of the year Mr. Wood has not been able to give as much time to this survey as formerly, because the newly developed instruments, of which some description will be given below, are now in actual operation, and the study of their behavior and of the character and scope of the results which can be obtained with them has required constant attention since January.

4. The Chilean Earthquake of 1922.

We were particularly fortunate in obtaining from the Carnegie Corporation of New York a special grant of $5,000 for the study of the great earthquake which occurred in Chile on November 10, 1922. Situated as it is on the west coast of the American Continent, like California, it was thought that a study of this destructive shock in Chile might throw considerable light on the California problem before us, while the California observations in turn might help to elucidate a similar problem in South America. The two situations did not prove to be as closely analogous as was anticipated, but the experience from each proved of value to the other.

Professor Bailey Willis, of this committee, spent six months (February to August 1923) on the ground in a careful examination of the visible evidences of the movement and of the geological formations of the region. He was accorded the fullest support and in many cases the close personal cooperation of officers of the government, of scientific bodies, and of commercial organizations. His Excellency the Ambassador of Chile at Washington, Dr. Beltran Mathieu, Dr. Xavier Gandarillas, Director of the Bureau of Mines (Santiago), Dr. Francesco Mardones, who has since become Minister, the Director General of State Railways, Don Rudoffo Jaramillo, and Dr. Johann Felsch, a geologist of the Bureau of Mines, were particularly helpful. Dr. Willis's conclusions will be found on pages 368 and 369.

5. The Development of Instruments.

The report of last year records the fact that after a conference between Dr. J. A. Anderson, of this committee, Mr. Wood, and a number of physicists of considerable experience in seismologic research, a new design of instrument of the Galitzin type was agreed upon and construction begun in the laboratory of the California Institute of Technology. This instrument has been completed, with the exception of the special galvanometer, the design and construction of which were undertaken by the Bureau of Standards under the direction of Dr. Frank Wenner. This part of the equipment has given some difficulty and is not yet available, so that no report can be made at this time upon the effectiveness of the new features which have been incorporated in it. It is designed to record the vertical component of the earth's motion.

Independently of this, Messrs. Anderson and Wood made a number of tentative experiments, with the purpose of developing an entirely new type of instrument, using the torsion principle, which is very much simpler than any heretofore used in seismology. It is a great pleasure to report that this work has been crowned with most remarkable success. An instrument of the utmost simplicity, adaptable to the measurement of any one of the three components of movement and capable of detecting short waves as well as long ones, has been perfected in a remarkably short time. Of the first two instruments of this type, which have been in use since January 1923, Mr. Wood, in his annual report, has given the following brief description:

"A cylinder of copper 2 mm. in diameter and 2 cm. long is soldered to a tungsten wire about 0.0008 inch in diameter (or to a ribbon made by rolling such a wire flat) so that the wire (or ribbon) is tangent to the cylinder parallel to its axis. A small mirror is attached to the system parallel to the plane through the wire and the axis of the cylinder. The wire (or ribbon) is stretched taut under suitable tension (about 15 grams) between supports placed so that the copper cylinder is held in the field of a permanent magnet strong enough to provide critical damping of the system under the conditions of use. To eliminate 'violin-string vibration,' the wire is passed through two castor-oil drops or films which do not oppose rotation or twisting of the wire appreciably.

"For registering horizontal motion the system is placed in a vertical position and adjusted until there remains little or no turning moment due to gravity, thus forming a *strictly horizontal pendulum* with a stable zero position and a restoring moment due wholly or predominantly to torsion. The period is, then, a function, other things being equal, of the lengths of the segments of the wire (or ribbon) suspension. Registration is conducted optically with photographic paper in the well-known way.

"These instruments may be transported with only ordinary care without injury or serious impairment of adjustment and, if fastened in position, they usually should survive a major earth shock from a near-by origin unharmed and ready to continue or resume registration.

"This principle is applicable for the registration of vertical seismic motion, as well as horizontal, and the instrument design is practically identical, but the theory of operation is less simple and not so easy to state briefly.

"The two seismographic recording mechanisms under construction in August 1922 were finished and shop tested, and in December 1922 were installed for trial and experimental operation—one in a basement at the Mount Wilson Observatory offices, under my own charge, and the other in a basement room of the Norman Bridge Laboratory of Physics at the California Institute of Technology, in the custody of Professor Walter T. Whitney. Upon trial both soon proved amply reliable and precise for the work required.

"A slow-motion, eight-day recording system has been developed also, and two have been constructed. These reel a strip of photographic paper 5 cm. wide at the rate of 3 cm. per hour for seven or eight days with one winding of the clocks, thus permitting close, as distinguished from open, registration for a week of one or more (as many as three) components of seismic vibration, all upon the same recording strip. Used with the torsion seismometers, these assemblies are intended primarily for routine recording of seismic acceleration (or intensity) at subordinate stations; but, in view of the simplicity and precision of the torsion seismometers, they will serve admirably in exploratory work or tests of the suitability of sites proposed for primary or secondary seismologic stations. Also, these will be useful in experimental field and laboratory studies. For this, within limits, these recorders may be speeded up to run at any desired rate. Moreover, they may be made to run very slowly to serve in recording long-period earth tilts."

With these first instruments more than one hundred local shocks were recorded between February and September (1923), and the great Japanese earthquake of September 1 left a very clear record, even though the instruments were not appropriately "tuned" to record distant shocks most effectively. It is of inestimable advantage to the future of seismology in all fields of activity (1) that these instruments may be varied in period to suit the particular group of vibrations which it is desired to study, or (2) several sets of instruments of different period may be maintained at the same station without becoming a serious burden.

6. Recommendations.

The early and remarkable success attained in the development of suitable instruments for the study of regional seismology has placed the committee in position to recommend the immediate establishment of the first group of stations and the systematic study of local earth tremors in southern California. Studies of local faulting in this part of the State, which have been carried on by Mr. Wood at intervals during the past two years, have provided the necessary information for selecting suitable sites and securing an advantageous grouping of observing stations. He says (Annual Report, 1923):

"It is desirable that a chief station, with facilities for experimental and development work as well as rôutine and research work, be established in the neighborhood of Pasadena—most advantageously on the area of granite which outcrops west of the city and the Arroyo Seco. A sound rock foundation and freedom from traffic disturbances, combined with proximity to the scientific resources of Pasadena and Los Angeles, unite in support of the desirability of this location.

"Then, for the first trial network of auxiliary stations—which may be modified if experience suggests it—stations equipped with three component assemblies of seismometric apparatus are recommended at Riverside, at Fallbrook in San Diego County (or, failing that, at some point not now designated specifically in the southeastern part of Orange County), and, if practicable, on the island of Catalina.

"The localities mentioned are favored provisionally on account of their geographic position and distribution with reference to one another and to the geologic faults most suspected of local seismic activity, and because of the crystalline or other well-consolidated rock to be found at or near the surface."

The Advisory Committee accordingly recommends to the President and Trustees of the Institution:

(1) Early provision for the equipment of a minimum group of provisional stations, in locations to be approved by the committee and fully equipped for the experimental study of regional seismology in southern Californa.

(2) Provision for a system of minute-to-minute standard time signals recording simultaneously at all stations.

(3) Provision for a set of seismographs recording in all three components at Mount Wilson Observatory.[1]

Your committee also earnestly recommends the continuance of the support hitherto given to the cooperative organization which has been effected both for assembling geodetic, topographic, geologic, and submarine physiographic data and for the further development of improved instruments of observation and measurement in this field.

It is further recommended that Mr. H. O. Wood, Research Associate in Seismology, be placed in charge of any stations that may be established.

J. A. Anderson,
Ralph Arnold,
W. W. Campbell,
Arthur L. Day (*Chairman*),
A. C. Lawson,
R. A. Millikan,
Harry Fielding Reid,
Bailey Willis,
Advisory Committee in Seismology.

Carnegie Institution of Washington,
October 1923.

Willis, Bailey, Stanford University, California. *Report on Chilean earthquake investigation.*

The methods and objects of investigation of the Chilean earthquake of November 10, 1922, were initially somewhat obscure. No one knew the character of the evidence which might be secured and no one knew exactly what scientific or practical purposes might be served. There was, therefore, a definite question as to what would result. Five months of field work demonstrated the following outcome:

On the scientific side the theory of elastic rebound as a prime condition of earthquake vibrations has been confirmed. This theory originated in the San Francisco earthquake of 1906 and was there developed according to the geologic structure, which is characterized by vertical faults; and it was with this structure in mind that I attacked the Chilean problem. It was found necessary to modify the mechanics of the explanation by substituting a nearly flat horizontal fault, situated 10 miles or more below the surface, for the vertical faults recognized in California. The flat structure characteristic of Chile was indicated by the enormous extent, some 300,000 square miles, of the Chilean earthquakes, and the existence of the type of structure peculiar to flat faults was evinced by extensive investigations in the Andes, up to 16,000 feet above the sea, and by detailed geological studies of the earthquake zone. It follows that the Cordillera of the Andes is being pushed eastward by a force which originates beneath the Pacific deep, and the mechanical structure of the mountains, which are intimately related to the ore deposits, depending upon the action of this pressure. This result has very far-reaching implications in geophysics and also in mining.

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[1] Lawson dissenting.

On the practical side, the problem presented was that of safeguarding the people against a repetition of disaster by designing quake-proof houses with the materials with which they are accustomed to building and within their very limited means. This problem has been solved by a study of the structures that stood during the earthquake, as well as of those which were ruined. It is essential to support the roof on a frame independent of the walls in order that the swaying of the one may not overthrow the other. That done, it is possible to build houses of adobe brick reinforced by galvanized fence wire at a moderate cost and within the limits of strength and flexibility required to resist such earthquake shocks as occur in Chile. Such houses are also reasonably fireproof. Another type of house which was successfully tested in the last earthquake consists of a wooden frame well mortised and wired on each face with tightly stretched fence wire in place of lath. The space between the wires on either face is best filled with mud brick, while over the wires plaster may be put as finish. A house of this construction went through the earthquake without even cracking the plaster. The results of these practical studies are incorporated in a pamphlet to be published in Santiago and distributed throughout the earthquake region.

The Chilean Government cooperated in every possible way to promote the investigation, and through President Alejandressi, as well as through several ministers, has expressed its urgent desire to continue its cooperation with the Carnegie Institution.

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